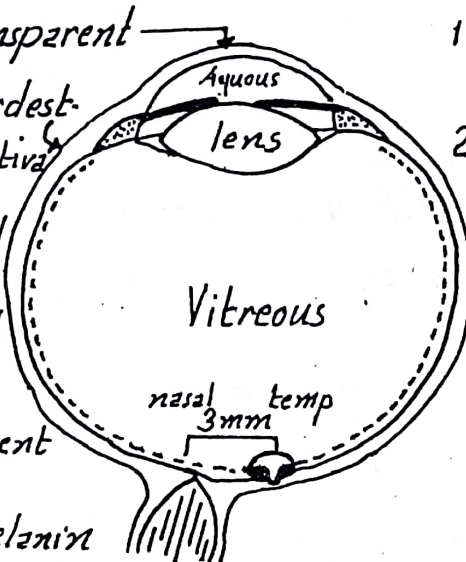


Vision

Physiology anatomy of the eye

3 layers :

- Outer**
- Cornea Ant $\frac{1}{6}$ transparent
 - Sclera Post $\frac{5}{6}$ hardest covered ant. by conjunctiva
- Middle coat**
- Iris Pigmented perforated disc (hole is pupil)
 - Ciliary body Ant ring Contains ciliary m ciliary processes suspensory ligament
 - Choroid Post. $\frac{5}{6}$ vascular rich in melanin
- Inner**
- Retina 10 layers Contains rods & cones. It contains

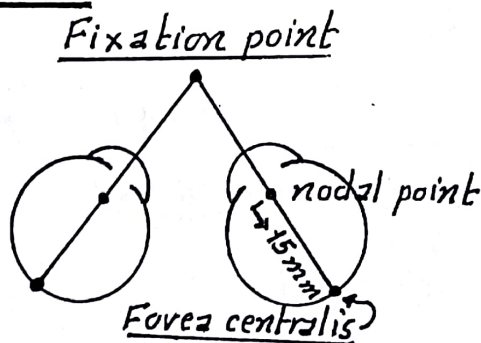


3 contents :

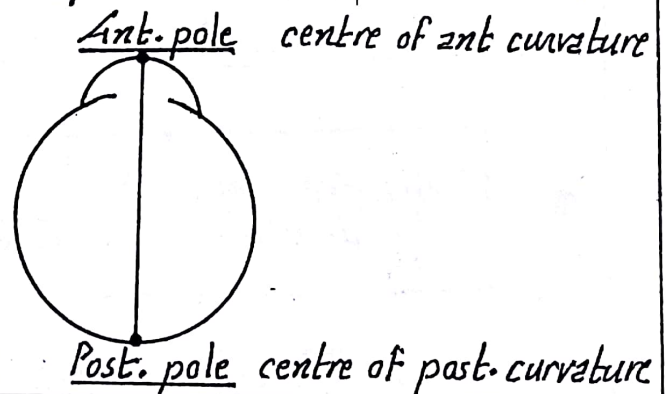
- Aqueous humour in front of lens
- lens attached to c. body by suspensory ligament
- Vitreous humour behind the lens RI 1.34. Supports retina & supplies glucose Viscid (albumin, hyaluronic acid)

- Macula lutea 1 mm^2 (fovea centralis 0.4 mm diameter) 3 mm temporal to optic disc opposite post. pole of eye.
- Optic disc (blind spot) 1.5 mm diameter site of exit of optic nerve.

Visual axis :



Optic axis :

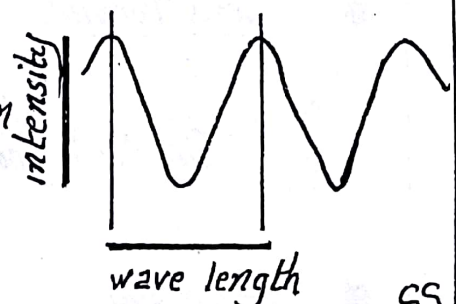


Electromagnetic radiation :

Light = visible portion $400 - 700 \text{ nm}$
 $4000 - 7000 \text{ angstrom}$
 Light consists of photons.

- White object reflects all spectrum colours.
- Black object absorbs all spectrum

Velocity of a wave = wave length $\times$ wave frequency (Hz) (1)



VISIT...

LANZAROTE
Caliente.COM

- Ultraviolet : Darkening of skin, kills bact & forms vitamin D
It may cause skin burning or skin cancer
- Infrared : Heating effect.
- Laser : Monochromatic light used in surgery & industry

Optics of the eye

Velocity of light in air & vacuum $300,000 \text{ km/s}$ > liquids & solid.

Light strikes an object may $\left[\begin{array}{l} \text{Absorbed} \\ \text{Reflected} \\ \text{Refracted} \end{array} \right. \rightarrow \text{Heat}$

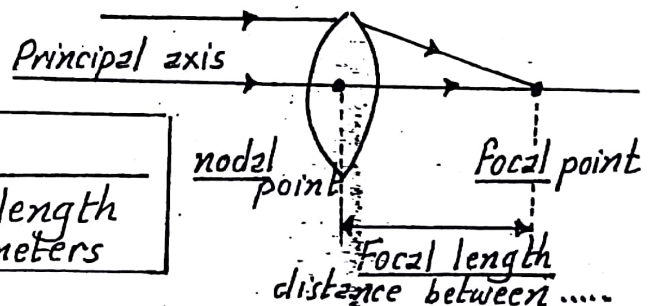
Refraction depends on :

- ① Refractive index of the medium . RI

$$RI = \frac{\text{velocity of light in AIR}}{\text{velocity of light in medium}}$$

RI of air = 1
RI of water = 1.33
(Aqueous H₂)
- ② Interface (plane or curved e.g eye)
 - Plane light falls - Perpendicular only light velocity changes
- Forming angle light velocity & direction change
 - Curved e.g convex spherical lens
- Parallel rays

$$\text{Refractive power (in diopters)} = \frac{1}{\text{Focal length in meters}}$$



- Divergent rays

• Lens Formula

$$\frac{1}{\text{Object distance (in meter)}} + \frac{1}{\text{Image dist. (in meter)}} = \frac{1}{\text{Focal length in meters}}$$

Dioptric power of resting eye = $\frac{1}{\infty} + \frac{1}{0.015} = 67 \text{ D}$

• Image size

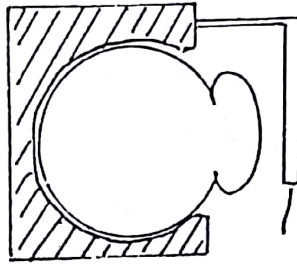
$$\frac{\text{Image distance}}{\text{Object distance}} = \frac{\text{Image length}}{\text{Object length}}$$

SS
(2)

Protective mechanisms of the eye

① Posterior $\frac{2}{3}$

bony orbit



② Anterior $\frac{1}{3}$

eye lids

3 Tear Film

4 Closure of eye lids Types of closure of eye lids

a Blinking

1 Reflex protective

a Tactile : corneal or ciliary reflex.

b Optic :

- Dazzle reflex : shining bright light.

- Menace reflex : moving object.

c Auditory : sudden loud sound.

10-12 times / min.

2 Spontaneous

3 Voluntary

b Voluntary winking

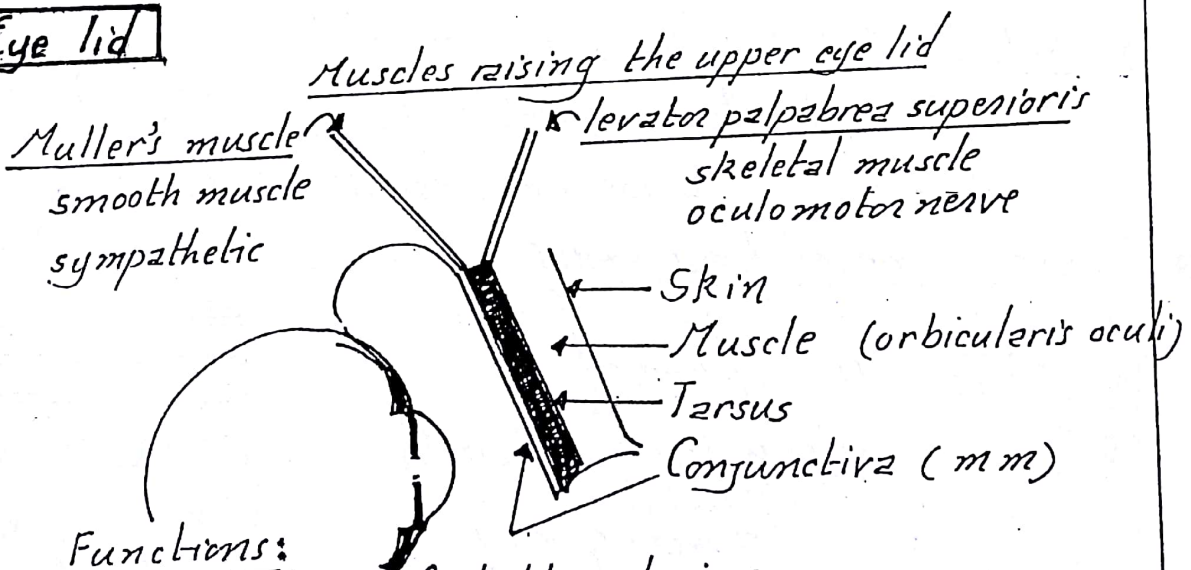
usually left.

c Blepharospasm

in eye injury.

5 Closure of eye lids during sleep.

Eye lid



Functions:

1 Regulation of light entering.

2 Protection.

3 Distribution & conduction of tears.

Lacrimal apparatus and tears

Lacrimal gland is supplied by Facial nerve VII (parasymp)

Tears Isotonic pH 7.4 RI 1.33

It contains NaCl , NaHCO_3 , Glucose & ptn.

- Composition:
 1% Lipid Meibomian glands.
 90% H_2O Lacrimal glands.
 rest Mucin Conjunctiva.

- Functions: 1 maintains optical uniform corneal surface.



2 corneal nutrition: gas exchange.

3 protection: lysozymes, lactoferrin & Ig G, M & A

4 lubrication: facilitates eye lid movement

Cornea

4 refractive interfaces ant & post surface of cornea & of lens

- Functions:

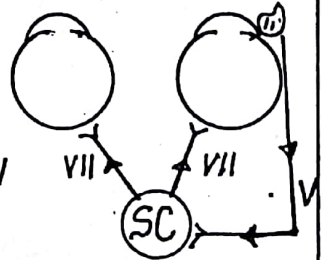
1 $\frac{2}{3}$ optical power of resting eye (67D) i.e 45D

Causes High degree of curvature diameter 11 mm.
 High RI 1.38 close to that of A. humour.

2 Protects delicate inner eye structure

N.B Corneal reflex (superficial R)

Aff V Centre Midbrain efferent VII



- Causes of corneal transparency:

1 Vessels: Avascular

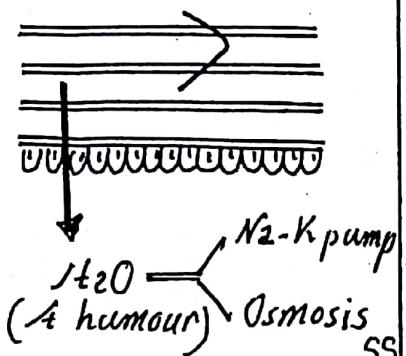
2 Nerves: Unmyelinated

3 Corneal Fibrils: uniform in diameter
 parallel
 regular spacing

4 Corneal dehydration:

Causes 1 $\text{Na}^+ - \text{K}^+$ pump

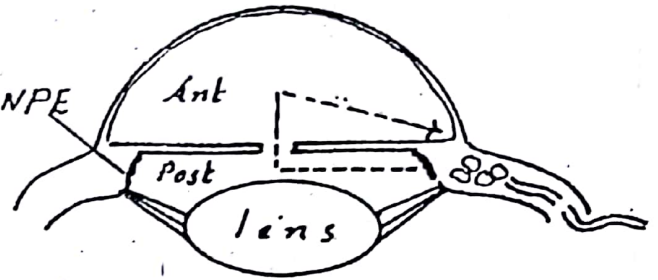
2 Osmosis: High Na^+ content of A. humour



(4)

Aqueous humour

- Def Fluid in $\begin{cases} \text{Ant} \\ \text{Post} \end{cases}$ chambers NPE
Alkaline clear fluid



- Formation: ciliary processes

① Active transport by inner non pigmented epith. layer (NPE)
 $\text{Na}^+ - \text{K}^+$ ATPase active transport systems C. anhydrase
Active Na^+ pump.

Cl^- & HCO_3^- follow passively.

② Nutrients e.g. glucose, amino acids & ascorbic acids
are transported by facilitated diff. or active mech.

- Composition:

differs from plasma. due to blood aqueous barrier.

Less glucose & ptn

More NaCl & lactate

- Circulation & drainage:

From Post. chamber $\rightarrow$ pupil $\rightarrow$ Ant. chamber
 $\rightarrow$ Irido corneal angle, then.

Episcleral outflow: via trabecular meshwork.
 $\rightarrow$ Canal of Schlemm's $\rightarrow$ Aqueous episcleral veins.

- Rate of formation and drainage: 2-3 microlitre/min

- Functions:

[1] It supplies O_2 and nutrients to cornea & lens.

[2] It drains metabolites.

[3] It maintains the intraocular pressure.

[4] It is one of the optical media of the eye.

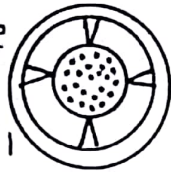
Intraocular pressure IOP

- Measurement: Tonometer or digital method
- Normal: 10-20 mmHg Highest in morning
- Regulation: regulation of outflow

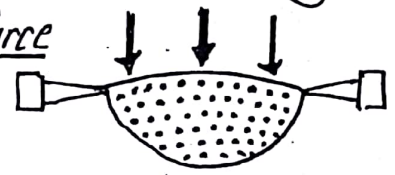
++ IOP $\rightarrow$ ++ flow in Schlemm canal $\rightarrow$ distend space of Fontana

- Functions
 - 1 It maintains the spheroid shape of the eye
 - 2 exerts 2 forces on lens → Flat (during rest)

Stretching force



Pressure force



• Glucoma: المياه الزرقاء

- Definition ocular p more than 21 mmHg
- Cause obstruction of outflow (trabecular space)
- Effects
 - 1 Blindness (common cause) due to retinal atrophy
 - 2 Failure to accommodate to near vision
 - 3 Severe pain (Headache).
- ttt
 - 1 Formation by Diazox (carbonic anhydrase inhibitor)
 - 2 ++ Drainage by Pilocarpine (pupilloconstrictor)
 - 3 Surgical by Opening the trabecular spaces

Concentric diminution of vision



Lens

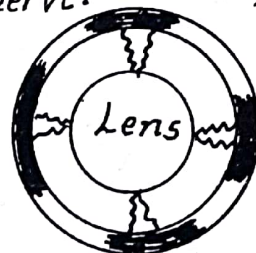
- Structure
 - Capsule elastic
 - Epith under the capsule
 - secretes capsule at equator
 - younger fibres at cortex - old fibres at nucleus
- Metabolism Very low It needs Glutathione
Energy is derived from glucose anaerobically
- Causes of lens transparency:
 - 1 Bl vessels : Avascular.
 - 2 Nerves : Absent.
 - 3 lens fibres : uniform distance is less than light wavelength
 - 4 Constituents: have almost the same RI 1.42
- Cataract: loss of lens transparency Cause: ultraviolet light
Cause: -- glutathione (antioxidant) & Ptn coagulation
- Dioptric power: $\frac{1}{3}$ 20 D at rest 34 D at full accommodation

Near response (Near reflex) written

- Def : Eye changes when the person looks at near object
- Mechanisms : ③ components ③ cranial nerve. (Reading)

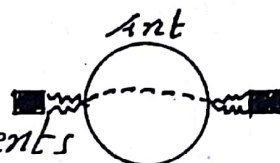
① Accommodation Involuntary

- = ++ dioptric power of lens.
via ++ Anterior surface curvature
i.e Diameter of " " 5.5 mm not 10 mm



• Mechanism 1 Ciliary ms : contracts

- circular fibres : -- pull on ligaments
- radial fibres : pull insertion forwards



2 Suspensory ligaments : lax

3 Lens : more spherical

- Power of accommodation : -- by age
10 Y = 14 D, 20 Y = 10 D, 50 Y = 2 D & 60 Y = 1 D.

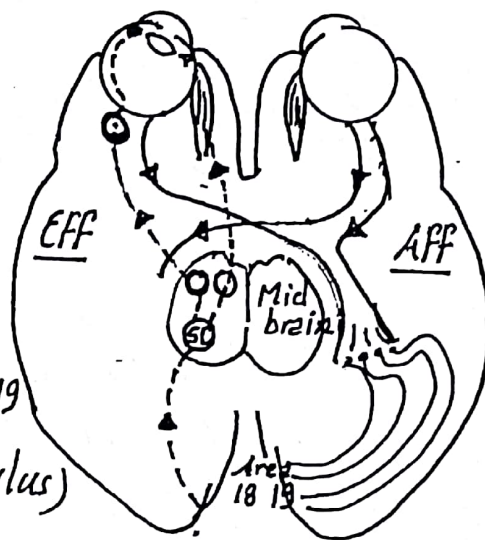
② Pupilloconstriction Involuntary

- light entering the eyes
- ++ depth of focus of lens

③ Convergence of eyes Voluntary to prevent diplopia (double vision)

● Nervous pathway :

- Afferent Visual pathway to area 18, 19
- Centre Midbrain (superior colliculus)
- Efferent Oculomotor nerve.



a Parasymp part. produces Accommodation & Miosis
i.e Edinger Westphal nucleus, Ciliary ganglion & short ciliary n.

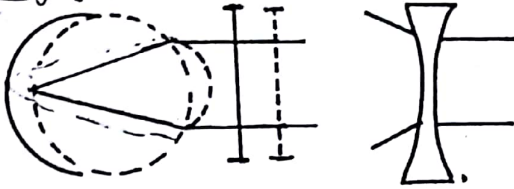
b Somatic part produces Convergence of both eyes

Note Parasympatholytic drugs e.g Atropine. → paralysis of accomod.
i.e cycloplegia and pupillo dilatation.

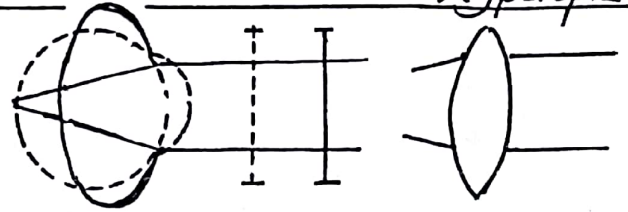
Errors of Refraction

written V.V.S.M.P.

1 Myopia: ^{نقص في الإبصار}
(العيان كان يجمع صور الأشياء في مكان يسبق)



2 Hypermetropia: ^{زيادة في الإبصار}
Hyperopia



Short sightness

Abnormally LONG eye
or v. strong lens so converge in front of retina
++ lens or corneal curvature

In front of retina

Divergence

Divergent lens

LESS than 10 cm

Less than 6 meter

Aggravates the condition

Eye ball

- Absolute

- Relative

Parallel rays converge

Pt needs more

Treated with

Near point

Far point

Accommodation

Far sightness

Abnormally SHORT eye

-- lens or corneal curvature

Behind the retina

Convergence

Convergent lens

MORE than 10 cm

Normal

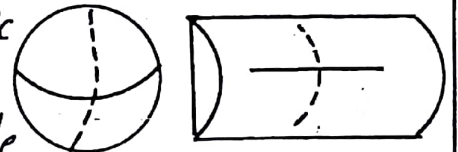
Essential for nears far vision
→ headache

3 Astigmatism: stigma = point

• Cause Asymmetrical corneal (or less common lens) curvatures

It may be myopic or hypermetropic

• Effects A point is seen as line
or line have a halo on either side



• It Cylindrical lens its curvature in the plane of error
or axis is perpendic. to the plane to be corrected

4 Presbyopia:

• Def.: -- Elasticity of lens by aging → -- accommodation

• Cause: -- Elasticity of lens due to ptn denaturation.

• Optical changes: Far point doesn't change
Near point recedes away from the eye
progressive -- in range of accommodation

• It: Convex lens for near vision only.

SS

8

Anatomy Iris

Its different colours are due to different degree of melanin pigments

Pupillo constrictor ms



Circular

Parasymp n.s III cranial n
(Edinger Westphal n.s ciliary g.)

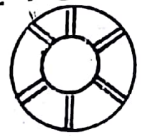
Strong

Fibres

N. supply

Tone

Pupillodilator ms



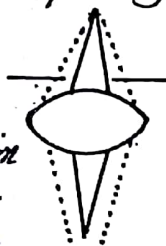
Radial

Symp n.s of head & neck
(Upper 2 T, super. cervical gang)

Weak

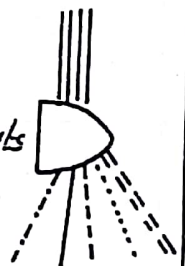
Functions of iris : written

1. Restricts passage of light rays to the pupil.
2. Regulates amount of light falling on retina
3. Prevents spherical and chromatic aberration
viz preventing light passage through peripheral parts (PPs) of lens
PPs have greater
Refractive power
→ different refraction
→ different focus
4. Constriction of pupil increases the depth of focus
i.e maximal distance object can move without blurring of its image
 $\text{Depth of focus} \propto \frac{1}{\text{size of pupil}}$



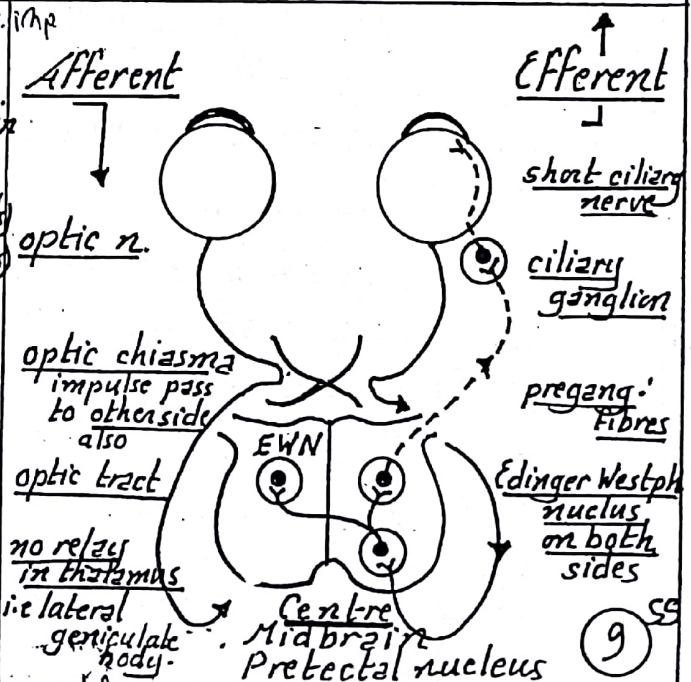
PPs act as prisms

Analyse white rays
into its spectral components



Light reflex (LR) : written N.V. imp

- Exposure of ONE eye to light results in constriction of BOTH pupils
i.e direct & consensual LR (2 components)
Cause of indirect or " LR (2 crossings)
- Nervous pathway Aff, Centre & Eff.
- Argyl-Robertson pupil
Cause lesion in pretectal nucleus due to neurosyphilis
Effects Pupil does not constrict with light but constriction with accom.
- N.B -- light intensity
→ slower pupillodilat.



Any eye reflex, center is midbrain

Causes of Miosis (meiosis)	Mydriasis i.e pupillodilatation
1 <u>Light</u> adaptation 2 <u>Near</u> vision i.e with accomod. 3 <u>Sleep</u> 4 <u>Horner's</u> syndrome. 5 <u>G. anaesthesia</u> stage (3) 6 <u>Orbicularis</u> (lid closure) reflex → miosis of same eye 7 <u>Pontine</u> hge (symp. lesion) 8 <u>Drugs</u>: irritate oculomotor - a parasympathomimetic e.g pilocarpine & eserine - b Morphine poisoning → pinpoint - c Histamine	1 <u>Dark</u> adaptation 2 <u>Far</u> vision 3 <u>Emotion</u>, fear, pain & asphyxia. 4 Lesion in <u>oculomotor n.</u> or its nucleus 5 Stage (2) pupil dilated & reactive Stage (4) pupil dilated & fixed 6 <u>Cilio-spinal</u> reflex i.e stim. of neck skin → mydriasis 7 <u>Glucoma</u> 8 <u>Drugs</u>: - a parasympatholytic e.g atropine → passive mydriasis (no LR) - b sympathomimetic e.g adrenaline → active mydriasis (LR present) - c Alcohol intoxication - d Cocaine (++ adrenaline sensitivity)

Functions of the choroid gives attachment to ciliary muscle.
 2 provides bl. supply to eye (highly vascular):
 3 prevents reflection of light inside eye (rich in melanin).

Retina

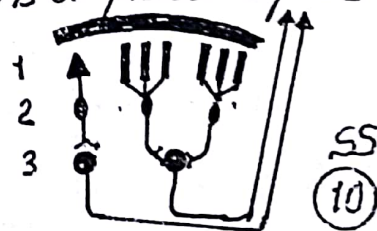
It is formed of 10 layers.

Visual acuity is highest at FOVEA because:

- 1 Light falls on cones directly (no other layers & no bl. vessels)
- 2 One to one connection (no convergence)
- 3 Pigment epith. layer of retina is highly developed. Its functions:
 - Absorbs light rays not absorbed by receptors (rods & cones).
 - Stores vitamin A.
 - Phagocytoses the membrane discs & debris of photoreceptors

Cellular layers of retina

- 1 Outer nuclear layer
 - 2 Inner nuclear layer
 - 3 Ganglionic cell layer
- photoreceptors
bipolar cells
horizontal cells
amacrine cells
no branches



N.B Photorecept. supplied by choroid capillaries so retinal detachment $\rightarrow$ damage.
Bipolar and ganglionic cells are supplied by retinal vessels

Horizontal cells = ^{inhibitory} interneurons Amacrine cells

- | | |
|--|--|
| <ul style="list-style-type: none"> - <u>Inhibitory</u> cells secrete GABA - Stimulated by rods & cones - <u>Function</u>: Lateral inhibition of rods, cones & bipolar cells | <ul style="list-style-type: none"> - <u>Excitatory</u> cells - Stimulated by bipolar cells - <u>Functions</u> Excite ganglionic cells
Indicate sudden change in light & detection of moving objects
Very rapidly adapting |
|--|--|

Characteristics of photoreceptors (Rods and Cones):

- 1 Outer segment: 1000 discs containing pigments
- 2 Inner segment: Mitochondria
- 3 Nucleus
- 4 Synaptic body: synapse with other retinal cells



Items written in V

Rods

Cones

Anatomical

1 Number

120 million / eye

6 million / eye

2 Site

Mainly at periphery
Absent in fovea

Centre of retina
Fovea contains cones only

3 Pigment

One type (rhodopsin)

Three types (red blue green for colour)

4 Convergence

200 rods converge to 1 bipolar
Many bipolar cells to 1 ganglionic

In fovea, one to one connection

Functional

1 Light sensitivity

Very high

Very low

2 Visual acuity

Very low (no details)

Very high (details)

3 Colour perception

No

Present

4 Vision

Scotopic (night vision)

Photopic (day vision)

5 Maximal sensitiv.

Green blue (500 nm)

Yellow 550 (nm)

Duplicity theory of vision

Von Kries theory

TWO separate mechanisms of vision (scotopic & photopic)
rods & cones

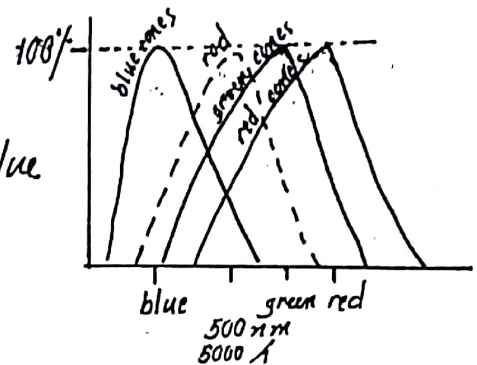
Purkinje shift phenomenon

<u>Shift from Cone (photopic)</u>	to	<u>Rod (scotopic) vision</u>
Colours		No colour (shades of gray)
Yellow most luminous		Green blue most luminous
		Red (not seen)

Prove of duality theory & Purkinje phenomenon:

① Photopigment absorption curve:

- Shows maximal absorption 100% for
- Rods at 500 nm i.e green-blue
 - Cones (3 pigments) at blue
at green
at red



② Bleaching sensitivity curve

Maximal bleaching occurs in the same range of maximal absorpt.

③ Retinal visibility curve

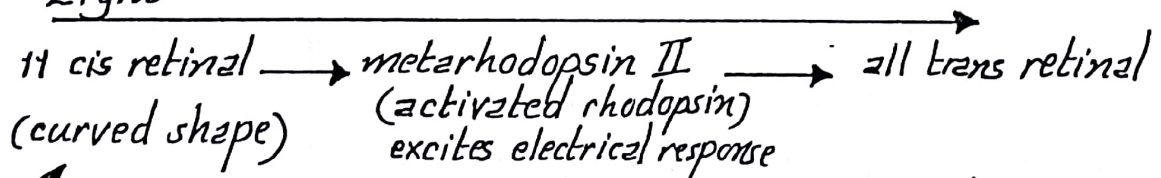
Rods have the least visual threshold at green-blue 5000 Å
Cones have the least visual threshold at yellow 5050 Å

Photoreceptor potential and signal transmission in retina 4

A) Photochemical changes (Bleaching)

Light separates opsin (ptn) from retinal

Light



Dark via retinal isomerase.

N.B Photoch. substance = Vit A derivative (11 cis retinal) + Opsin

Opsin scotopsin or photopsin (3 types)

Vit. A is important in rhodopsin formation.

So, Vit A deficiency $\rightarrow$ nyctalopia
 $\rightarrow$ degeneration of cones
 $\rightarrow$ " of neuronal layers of retina

SS

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B) Genesis of electrical response :

Photoreceptor potential

Dark (resting condition)

Depolarization - 40 mV

Mechanism:

- inner segment : Na^+ pump
- outer segment : Na^+ leaks into
i.e dark current
channels kept open by cGMP

→ Depol

→ $\oplus\oplus$ release of ch. transmitter

Notes:

- Rods are extremely sensitive to light & their potential lasts longer time than cones ; because of summation
- Regeneration of cGMP in dark is caused by :
1 -- rod Ca^{++} activates guanylate cyclase & inhibits phosphodiesterase
2 Rhodopsin kinase inactivates metarhodopsin II

D) Signal transmission in retina :

by Generator potentials which allows graded conduction of signal.
Except Ganglionic & amacrine cells which conduct by action potential.

C) Excitation cascade :

Light exposure

Hyperpolarization

Mechanism:

Photons

activate rhodopsin

» transducin (G pbs)

» cGMP phosphodiesterase

-- cGMP

Na^+ channels

→ Hyperpolar - 70 mV

→ $\ominus$ release of ch. transmitter

The receptive fields of Ganglionic Cells :

are organised into two

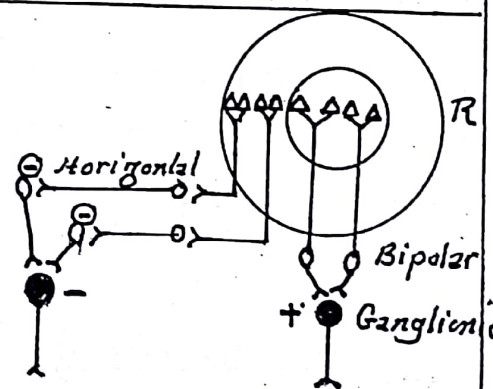
a On centre - OFF surround receptive field

b Off centre - On surround " "

i.e they show LATERAL INHIBITION

viz inhibitory horizontal cells

Object to sharpen the edges of the stimulus.



Horizontal

Bipolar

Ganglionic

Light

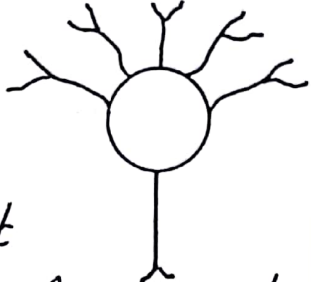
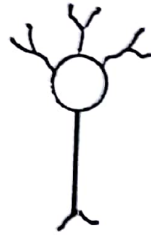
Light

- +

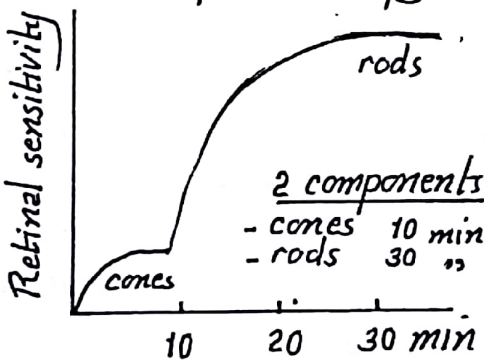
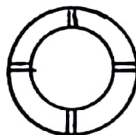
+ -

SS
(13)

Types of ganglionic cells:

M Magno cells		P Parvo cells
Large Large High Transient Detection of movement & change in light intensity 	<u>Size of cell</u> <u>Receptive field</u> <u>Conduction velocity</u> <u>Discharge</u> <u>Function</u>	Small Small Slow Sustained Involved in color vision , texture & fine details 

Automatic regulation of retinal sensitivity Retinal adaptation

Dark adaptation		'Light adaptation
(++) retinal sensitivity to light i.e. (--) retinal threshold. 100,000 to 500,000 times <u>30 minutes.</u> 1 <u>Regeneration</u> of photosensitive pigments  2 <u>Mydriasis</u>  3 ++ Signal intensity in retinal neurones 4 ++ Retinal sensitivity to light	<u>Definition</u> (--) retinal sensitivity i.e. (++) retinal threshold. <u>Time</u> <u>5 minutes.</u> <u>Mechanism</u> 1 <u>Breakdown</u> of photosensitive pigments 2 <u>Miosis</u>  3 -- Signal intensity. 4 -- Retinal sensitivity.	

Discuss Vitamin A page 12

Color vision

Ability of retina to distinguish colours

Young - Helmholtz theory

- 3 cones
- 3 pigments
- 3 colours

- Colour sensation depends on:
the relative frequency of impulses in each of the 3 cones
e.g. equal stim. of the 3 cones $\rightarrow$ white colour

- Colour perception is a RETINAL phenomenon.

Colour translation is a CORTICAL phenomenon.

i.e. It depends on colour coding.

- Neuronal mechanism of colour vision

Information is carried by small (parvo) ganglionic cells

$\rightarrow$ parvo cellular neurones in lateral geniculate body (thalamus).

$\rightarrow$ neurones of blobs of visual cortex

$\rightarrow$ lingual and Fusiform gyri of occipital cortex (colour area).

Notes

- Hue actual colour.
 - Prim. colours red, blue, green.
 - Complementary colour when mixed $\rightarrow$ white e.g. yellow and blue
- Saturation: purity of colour from white
Brightness: number of photons/area/second

Colour blindness

- Causes 1 Hereditary: x linked recessive σ^2 8% f 0.04%

2 Retrobulbar neuritis:

- Types:

Cone system

Subtypes

1 Mono chromate



Pt match colours by varying intensity

2 Di chromate



one is absent

1 Protanopia red blindness

2 Deutanopia green " (2nd common)

3 Tritanopia blue "

3 Anomalous trichromate



one is weak

1 Protanomaly red weakness

2 Deutanomaly green " (most common)

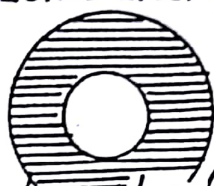
3 Tritanomaly blue "

- After image = Visual sensation after removal of visual stimuli

Types:

[1] -ve after image

- a Bright portions appear dark due to Light Adaptation.
- b Dark portions appear bright due to Dark Adaptation.
- c Colour portions appear as their complementary colours.



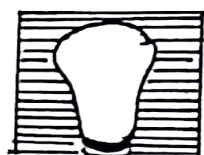
ADAPTATION



[2] +ve after image

The image of the bright object is still seen after closing the eye for few seconds

AFTER DISCHARGE



- Flicker = intermittent light sensation

Flickers disappears at Critical Fusion Frequency CFF
Cause After discharge.

Importance Motion pictures

Ferry Porter law $CFF \propto \text{light intensity}$

CFF for rods 20 & cones 50 Hz i.e. shorter after discharge for cones

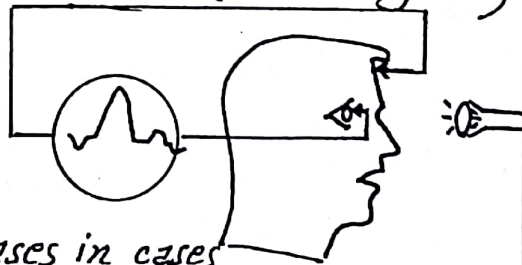
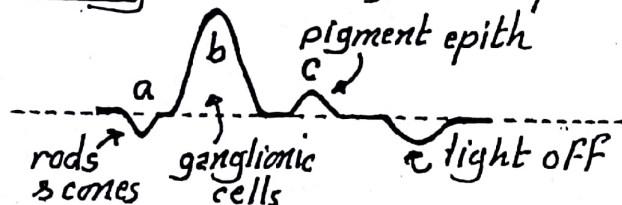


- Electroretinogram (ERG)

Def: record of electrical changes in retina on exposure to light.

Method Exploring electrode on cornea & indifferent elect. on forehead

Recording At rest, 6 mV potential difference (front of eye +ve)



Importance Diagnosis of retinal diseases in cases of difficult retinal visualization e.g. dense cataract.
In Retinitis pigmentosa, rods are affected 1st → no a wave

Visual pathway

Photoreceptors: rods & cones

1st order neurone: bipolar cells

2nd order neurone: ganglionic cells

Axons form

- optic nerve 1.2 million fibre (1/3 macula)
- optic chiasma

- . nasal fibres cross
- . temporal fibres don't

- optic tract which sends

1 Pretectal nucleus: light R

2 Superior colliculus: reflex eye directional movement

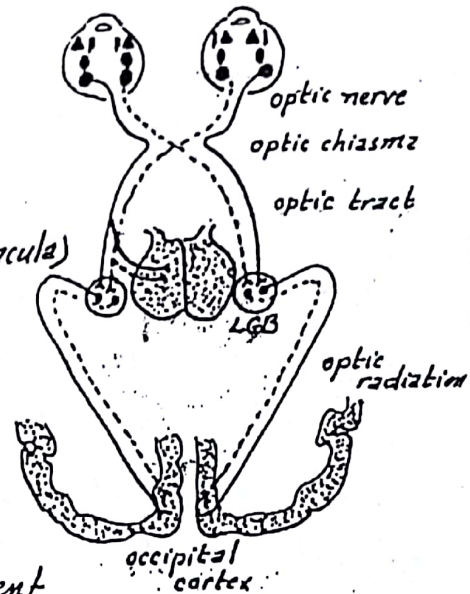
3 Hypoth (suprachiasmatic nucleus) light evoked endocrinal fun.

4 Thalamus (lateral geniculate body) 3rd order neurone

Layers 2, 3, 5 ipsilateral eye 1, 4, 6 contralateral eye.

Layers 1 & 2 magno cells 3 & 6 parvo cells

Neurones of LGB have the same organization of receptive field of ganglionic cells.



Visual cortex

[1] Primary visual area = area 17 = striate cortex

Site calcarine fissure on medial surface of occipital cortex

Organisation

- Visuo topic representation Macula: post part occipital pole
Periphery: ant part

- 6 layers geniculo-calcarine fibres terminate in layer 4
Simple cells → Complex cells (Discuss page)

- Columns 20-100 μ wide contains 3 types of cells
Blobs or p. agrion (colour processing layers 2, 3 between columns)

Function: Decode information of colour, depth, form & movement

[2] Visual association area = areas 18-19 = peristriate area

Site anterior, superior and inferior to prim. visual cortex

Functions: Analysis of signals received from area 17.

a Detection of the nature of objects

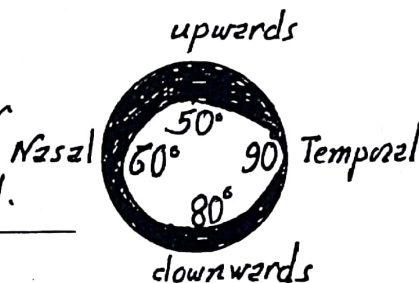
b Visual orientation and depth perception

c Sends information to other cortical areas 7, 8, 20 & 21 (17)

(7 post. parietal, 8 frontal eye field, 20-21 inferior temporal area)

NB Simple cells: have rectangular receptive fields with specific axis.
 Respond to bar of light or lines with particular orientation
 If a bar of light is rotated 10° or more $\rightarrow$ -- discharge till it disappears
Complex cells respond best to moving (dark or light) bars.
 receive impulses from simple cells.

Visual Field = Maximal area seen by ONE FIXED eye
Represented in area 17 diagrammatically opposite to retina
 i.e temporal half of retina sees the nasal half of field & vice versa.
Normally, not circular
 Most extensive for white target, then smaller
 for blue, red and green targets successively.



Lesion	Effect
1 Rt optic nerve	Blindness of Rt eye
2 Centre of optic chiasma	Bitemporal hemianopia (telescopic vision)
3, 4, 5, 6	Contralateral homonymous hemianopia
3 Optic tract	Light reflex is absent.
4 Lat. geniculate body	Light reflex is present.
5 Optic radiation (extensive)	Light reflex is present.
6 Occipital cortex	Macular vision is spared
7 Macular region in area 17	Contralat hemianopic scotoma. (loss of central eye field of both eyes)
8 Visual association area	Visual agnosia (Pt sees but can't understand)

9 Optic radiation (not extensive) Contralat homonymous quadrantanopia
Macular sparing is due the fact that macula is widely represented in CC.
 ; macular region has double blood supply & bilateral representation.

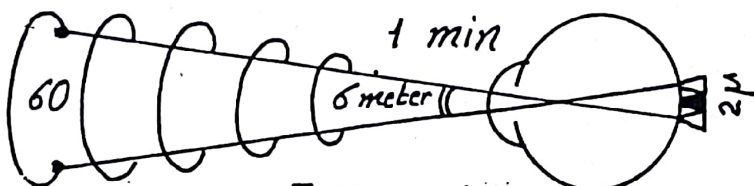
Visual acuity = Ability to see 2 points as 2 separate points
 - Requirements + Visual angle 2 points & nodal point of eye
 not less than 1 minute SS (18)

or 2 - Two images must fall on 2 cones separated by at least one unstimulated cone i.e retinal distance more than 2μ

Tests :

1 Landolt chart

broken circles C



7 rows 6, 9, 12, 18, 24, 36 & 60

2 Snellen's alphabetical letters

The person stands 6 meter from the chart (no accommodation)

If he is able to see up to 18 only, he is 6/18

Factors affecting visual acuity

- ① Illumination and contrast
- ② Pupilloconstriction minimises aberration
- ③ Errors of refraction
- ④ Eye diseases
- 5 Maximal at fovea centralis

Eye movements

- Each pair of 3 sets of eye ms is reciprocally innervated e.g. ^{Rt lat rectus contract} ^{Rt Med. " relaxes}
- Conjugate eye movements are controlled by area 8 and area 19

- Types of eye movements :

- 1 Saccades Sudden Jerky during reading 2-3/sec.
- 2 Smooth pursuit Fixation on moving object Optokinetic nystagmus
- 3 Vestibular Visual Fixation as head moves (impulses from SCCs)
- 4 Convergence on looking to near object.
- 5 Fixation lock the in a new position to see details
Voluntary Fixation unlocking (Area 8) then involunt Fixation (Area 19)

N.B Physiologic nystagmus prevents recept. adaptation to constant illumination

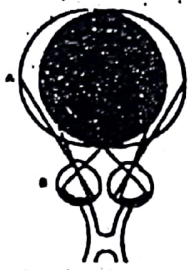
Strabismus or Squint → loss of conjugate mov. → diplopia
Under 6 years if not corrected → permanent -- of acuity amblyopia
exanopsia

Ophthalmoscope = instrument for retinal examination.

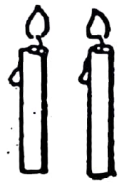
- 1 Examination of retinal blood vessels mainly arterioles
It helps diagnosis & prognosis of DM, hypertension & retinal disease
- 2 Examination of fovea & optic disc e.g. glaucoma and brain tumour
- 3 Diagnosis of retinal diseases e.g. retinal detachment.
- 4 Determination of error of refraction.

Binocular vision

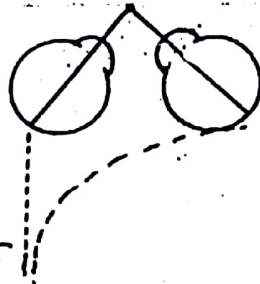
- Definition: Ability to use both eyes without diplopia (double vision)
- Requirements:



Two visual fields



TWO IMAGES



- Factors:

must overlap to a great extent "	Identical Two eyes equal dioptr. power "	Fall on 2 corresponding points → single visual sensation Normal extrazocular ms visual cortex "
-------------------------------------	--	--

• Advantages:

- ① Large visual field.
 - ② Defect in one eye is corrected by the other.
 - ③ Abnormal refraction of one eye is corrected by the other.
 - ④ Better stereoscopic vision
 - ⑤ Better depth perception
-] essentially monocular.

In monocular vision, depth and distance depend on:

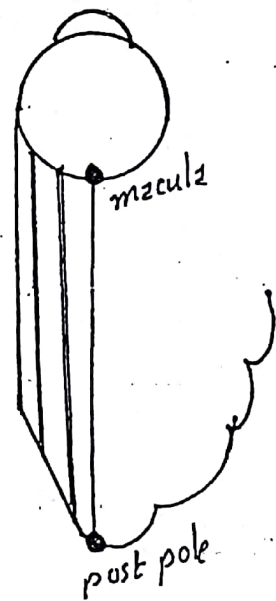
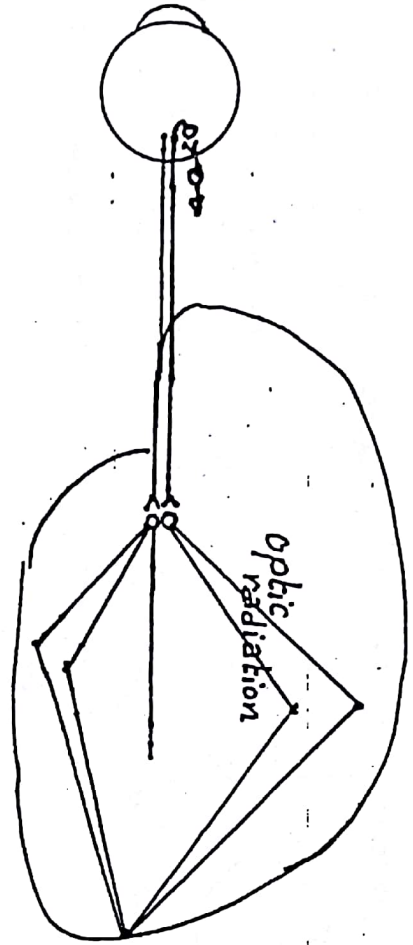
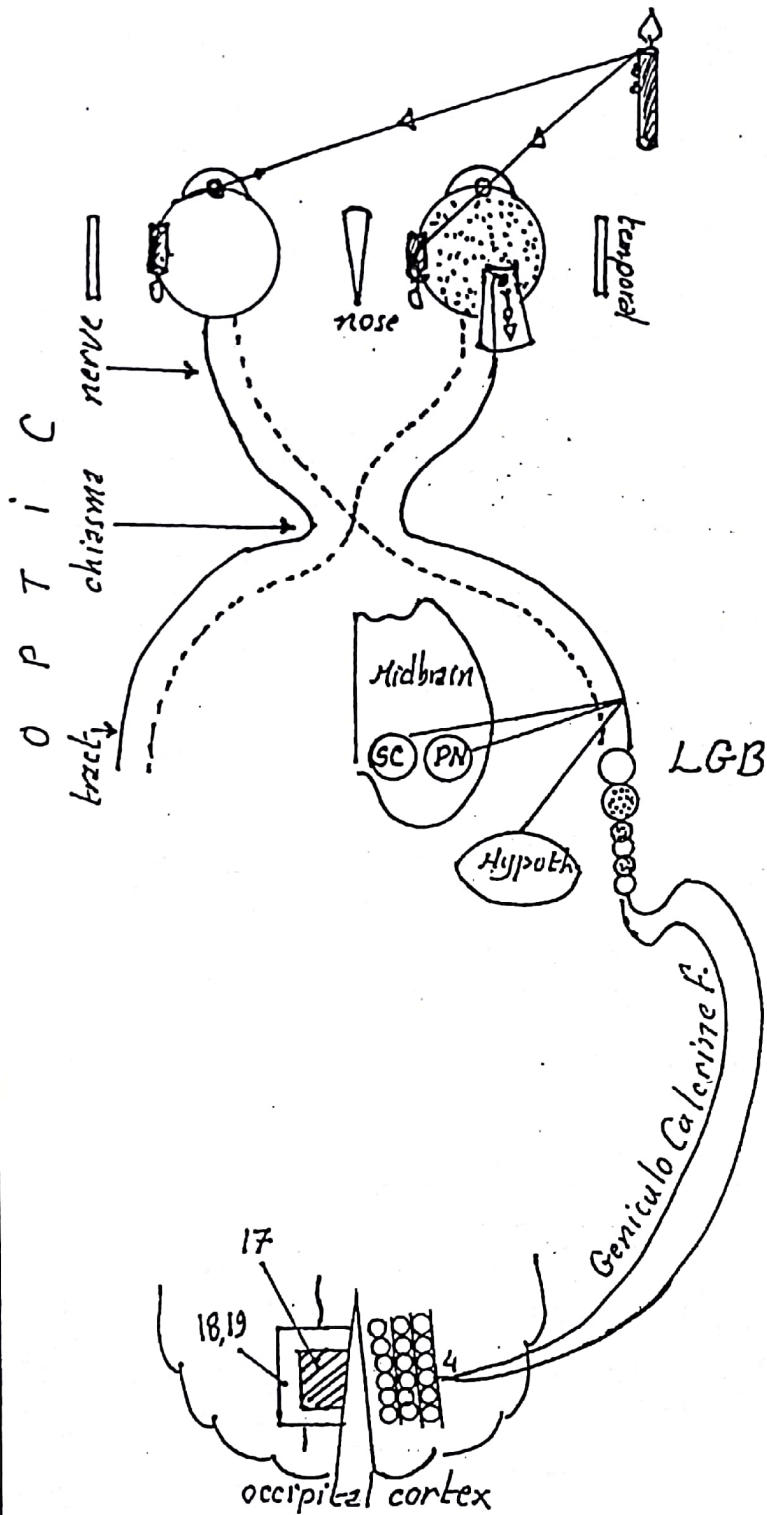
- 1 Change in size
- 2 Occlusion of far by near object
- 3 Colour & details fade in far
- 4 Distribution of light and shades
- 5 Shadows cast by object upon its surrounding.
- 6 Perspective: Parallel lines appear to converge with distance.
- 7 Parallax: near object moves in opposite direction & far object moves in same direction

Stereognosis = 3 dimensional vision

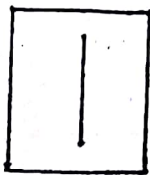
Cause in monocular: Factors that determine depth perception. 55

In binocular: Formation of 2 slightly different images → Fusion (20)

Good Luck



خلم ثابت
خلم متحرك
مستوى واحد

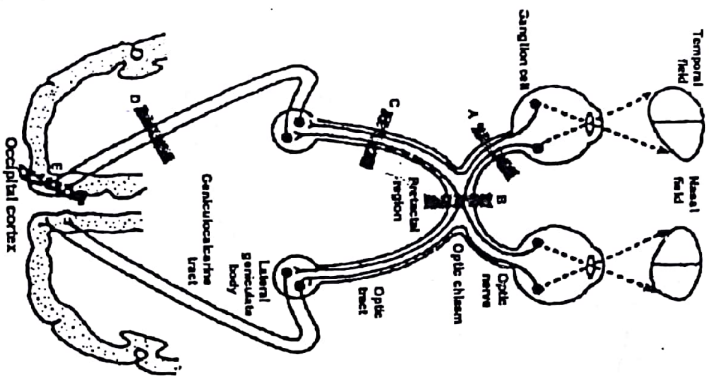


Simplex



Complex

Visual Lesions

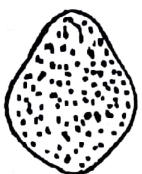


Lesion of optic chiasm

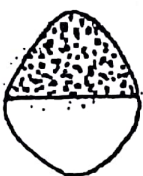
- Central binocular hemianopia
 - Lateral nasal hemianopia
- Macula central hemianopia scotoma
- Lesion in visual association areas:

Visual agnosia.

ie sees but cannot understand.



4



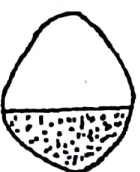
3

Bitemporal Hemianopia



5

Absent light reflex



0

Light reflex is present



7

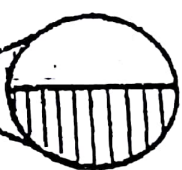


Macala is spared

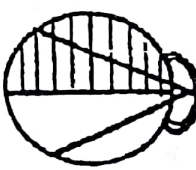
Contra/lateral Homonymous Hemizotropia

Visual Field

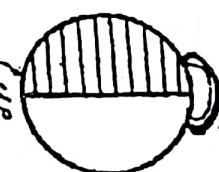
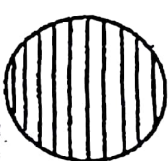
seen by one fixed eye



Fire Id



645

~~Apr 17~~

55

Hearing Sound waves

waves of compression & rarefaction of molecules



can't pass in vacuum.
 $\neq$ light [velocity in gases $\leftarrow$ liquids $\leftarrow$ solid $\leftarrow$ Velocity = wave length $\times$ Hz
 340 m/s 1500 m/s $++$ by temp not affected by atmosph. p.

Characters of sounds:

1 Frequency (pitch = tone "harsh or soft") of sounds

Human ear 20 Hz 20,000 Hz

most sensitive to human voice 2000 - 5000 Hz

Ultrasound more than 20,000 Hz use $\left\{ \begin{array}{l} \text{Diagnosis: Echocardiography} \\ \text{Heat} \end{array} \right.$

2 Amplitude (loudness = intensity "high or low") of sounds

It is measured in Bels or better Decibels (dB).

It is " in a relative way.

$$\text{dB} = 20 \log \frac{\text{Pressure of sound stimulus}}{\text{Pressure of reference sound (Just audible threshold)}}$$

1	Just audible	=	0	dB
2	Whisper	=	40	dB
3	Normal conversation	=	60	dB i.e 1000 times
4	Traffic noise	=	80	dB
5	Pneumatic drill or airoplane	=	100	dB
6	Jet plane	=	120	dB
7	Painful damaging sounds	=	140	dB or more

3 Quality of sounds:

Depends on waveform i.e overtone.

Audiometer It measured the degree of hearing loss.

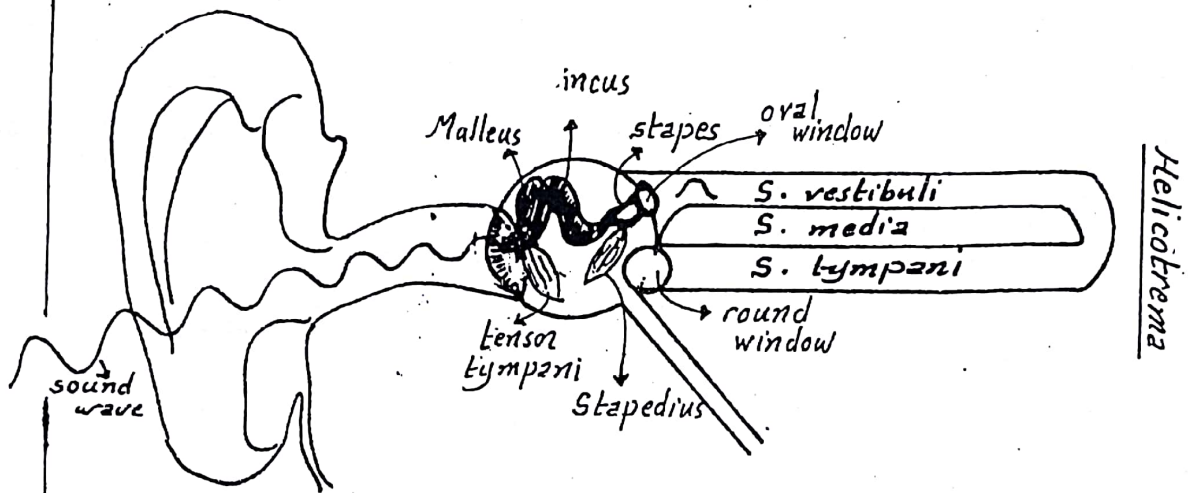


Range of test 125 - 8000 Hz of pure tone.
 in a sound proof room.

By air and bone conduction

Presbycusis -- ability to hear high frequencies in old age (21)

Structure of ear



External

- 1 Pinna.
 - 2 Ext. auditory meatus.
 - 3 Tympanic mem.
 - 1 cm diameter.
 - 0.1 mm thickness
 - 55 mm² cone shaped
 - covered by skin 3 mm
- characters
- Elastic.
 - Tense.
 - Aperiodic: no natural F
 - Damped: stops if sound stops

Middle

- 1 Eustachian tube
- 2 Mastoid air cells
- 3 Mesotympanum
 - It contains:

a Air

b Three ossicles

c Two muscles → Attenuation (Tympanic) R

- Tensor Tympani
 - Trigeminal
 - Pulls malleus inwards
- Stapedius
 - Facial
 - Pulls stapes away from oval window
 - Prior to vocalization & chewing

Inner (cochlea)

- 3 cm length
- 3 turns (2½)
- 3 canals or scalae

F u n c t i o n s

- 1 Collection of sounds
- 2 ++ sound pressure on tympanic mem
- 3 Sound localisation
- 4 Protective function
 - wax bactericidal
 - air moist-swarm

- 5 Function of Tym mem.
 - transmits vibration from external to middle ear

- 1 Conducts sound
- 2 Protection of cochlea
- 3 Impedance (resistance) matching
 - Air to fluid
 - Amplifies 22 times
 - 17 times area ratio
 - 1.3 ossicles act as lever

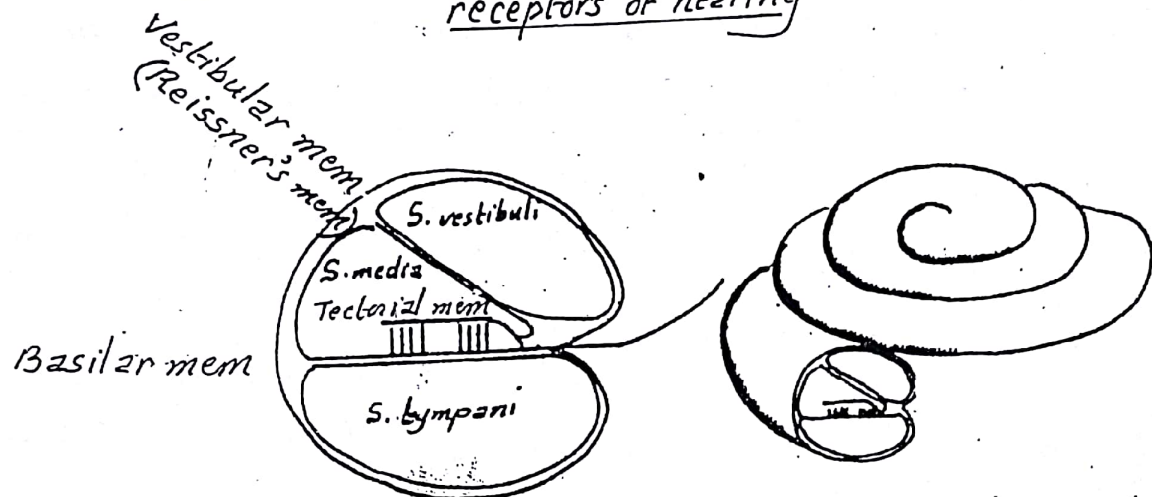
- 4 Ossicular system.
- 5 Muscles.
- 6 Eustachian tube.

Perception of sounds
i.e. receptors
Organ of Corti

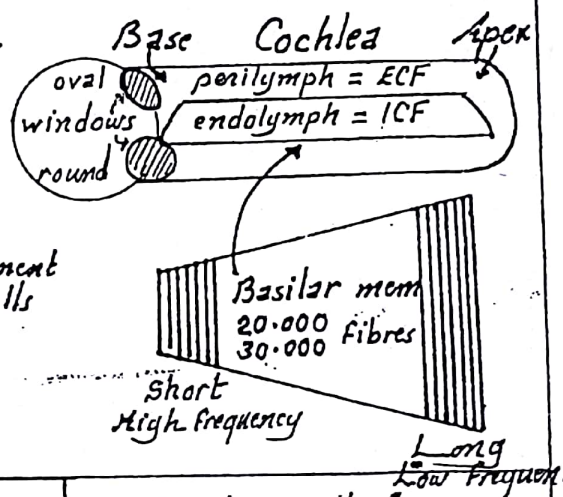
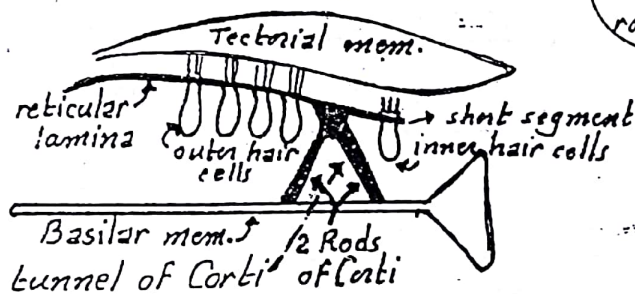
SS

(22)

Cochlea and organ of Corti receptors of hearing



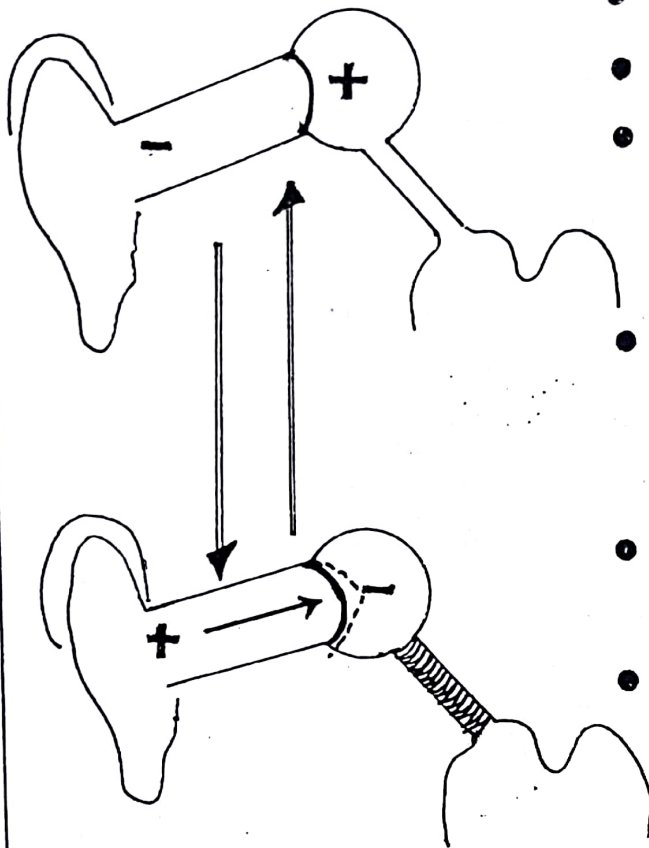
Hair cells are bathed in endolymph.
-150 mV then "



Items	Inner hair cells	Outer hair cells
<u>Site</u>	Medial to tunnel	Lateral to tunnel
<u>Number of rows</u>	One	Three
<u>Number of cells</u>	3500	20,000
<u>Innervation</u>	90-95 %	Few 5-10 %
• Afferent		Most of efferent
• Efferent	Few	Improve hearing
<u>Function</u>	Auditory recept.	affects vibration of basilar membrane

- Scala media contains endolymph = intracell. fluid.
- Scala $\left\{ \begin{array}{l} \text{vestibuli} \\ \text{tympani} \end{array} \right.$ contain perilymph = extracell. fluid
- Endolymph is formed by stria vascularis in scala media
- is -ve in comparison to perilymph

Eustachian tube



- Connects middle ear with nasopharynx
- Equalises p. on both sides of drum.
- Normally closed and open during :
 - swallowing, yawning & chewing.
 - Ascend to high altitude.
- During Descend, it doesn't open
Drum is displaced
 → pain & may rupture.
- If open all time, sounds of breathing and talking will interfere with hearing.
- Cilia act in one direction allowing drainage
In children, tube is short, wide & straight causing easy middle ear infection.

Mechanism of hearing

- 1 Transmission of sounds
- 2 Stimulation of receptors
- 3 Transmission of auditory impulses to the cortex
- 4 Discrimination of sounds by the cerebral cortex

① Transmission of sounds

a Ossicular route: Main route

Drum $\rightarrow$ ossicles $\rightarrow$ oval mem.

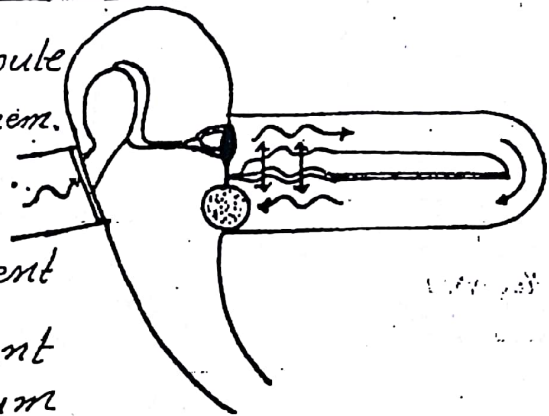
Advantages: Functions of middle ear

b Bony route inefficient

c Air route inefficient

Important only when drum and ossicles are damaged

Sensitivity: 15-20 dB less than ossicular route.



② Mechanism of stimulation of auditory nerve

Generation of receptors potentials

- Sound waves entering the inner ear from oval window
- As sound energy passes from the scala vestibuli to the scala tympani, it causes the basilar membrane to vibrate up and down.
 - $\rightarrow$ stereocilia of hair cells to bend back & forth

a When the organ of Corti moves up

- $\rightarrow$ the stereocilia bend away from the limbus
- $\rightarrow$ opening of K^+ channels
- $\rightarrow$ K^+ flows into the hair cells
- $\rightarrow$ depolarization
- $\rightarrow$ opening of Ca^{++} channels
- $\rightarrow$ Ca^{++} enters the hair cells
- $\rightarrow$ release of a synaptic transmitter
- $\rightarrow$ stimulation of auditory nerve fibres

b When the organ of Corti moves down

- $\rightarrow$ the reverse occurs

Auditory pathway

5 points

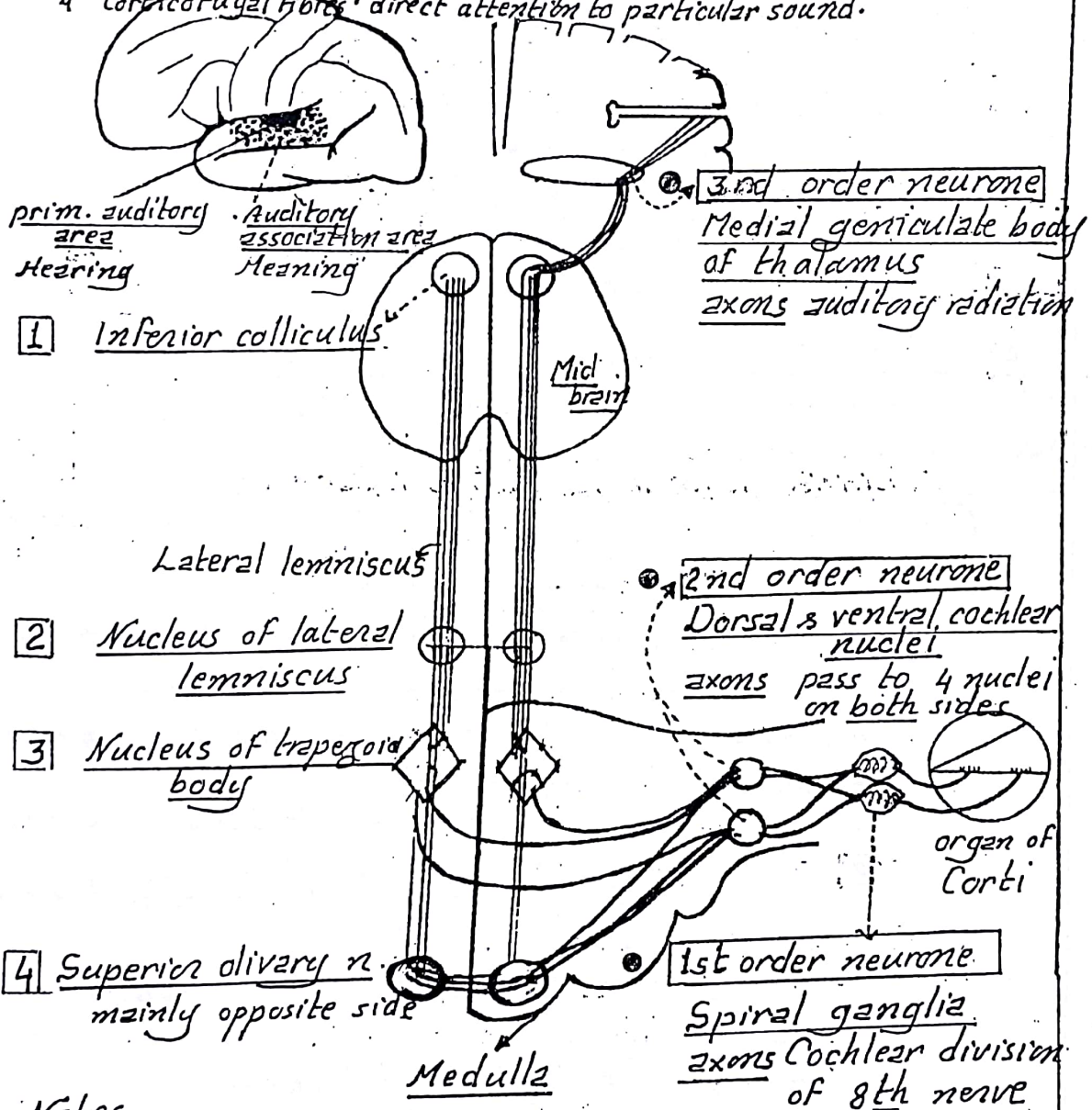
• Auditory cortex :

Functions

- 1 Perception of sounds & sound pitch
- 2 Sound localisation
- 3 Recognition of patterned sequence of sound.
- 4 Corticofugal fibres direct attention to particular sound.

• Receptors

Organ of Corti
inner hair cells



Notes

- collaterals to reticular activating system
- Bilateral destruction of auditory cortex
 - no complete deafness
 - no recognition of tone & sound localization.
- Unilat. destruction slight -- in hearing in opposite side.

SS

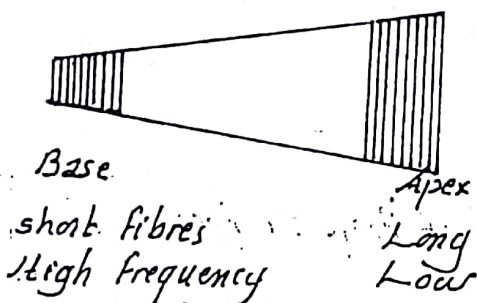
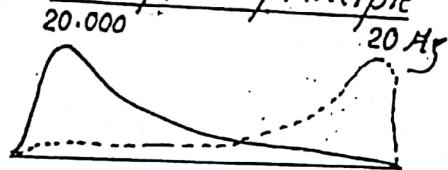
(26)

Auditory code

Ability of the auditory system to determine (discriminate)

A Sound frequency pitch

① The place principle



Any sound produces a travelling wave causes peak depression of basilar mem i.e. maximal receptor stimulation at one point (place)

- At the base, in case of high pitch
- At the apex, in case of low pitch

Distance from stapes $\propto \frac{1}{\text{pitch}}$

② Tonotopic organisation

There is spatial organisation of fibres & neurons for each pitch all the way from cochlea to cerebral cortex.

e.g. at any nucleus: Neurons of low frequency at one end. " " of high " " at opposite end.

B Sound intensity: it depends on the

- 1 Frequency of action potential i.e. Weber-Feshner law
- 2 Number of activated auditory nerve fibres
- 3 Outer hair cells are stim. significantly only with loud sound.

C Sound localization: it depends on

- 1 Intensity difference sound is louder in the closer ear
- 2 Phase Difference sound arrives 1st to the closer ear
- 3 Pinnas of both ears help localization. This is more import. in low frequencies if sound source is in front, behind, above or below the person.

D Sound pattern: i.e. combination or sequence of tone

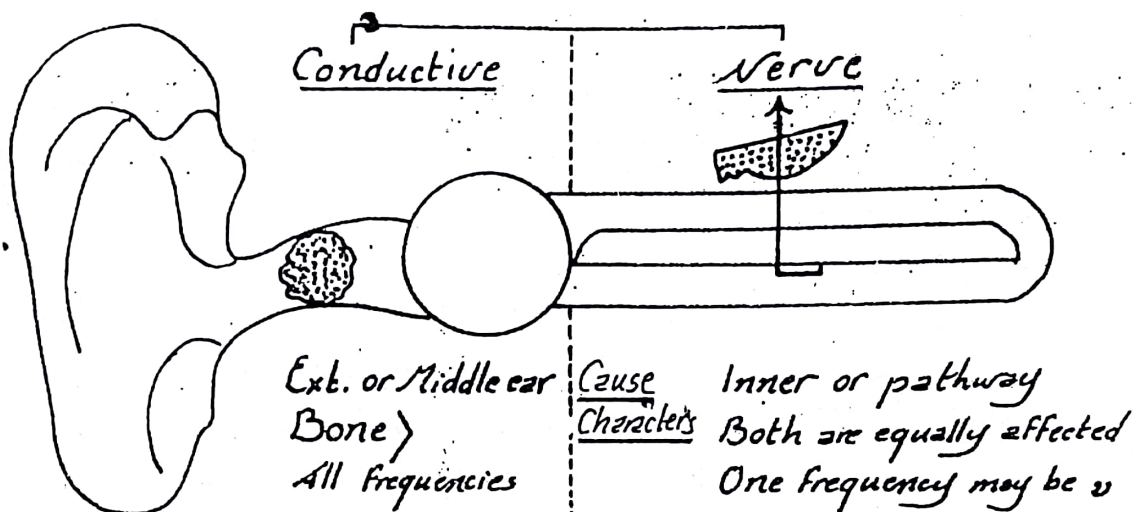
It occurs at the auditory cortex

It responds specifically to shift from high to low frequency

It is impaired by lesion in auditory cortex

Deafness

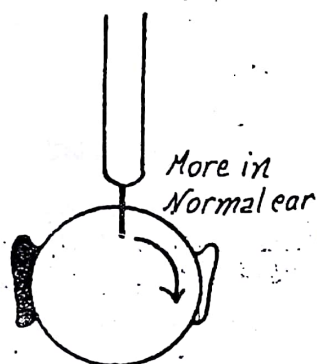
2 types:



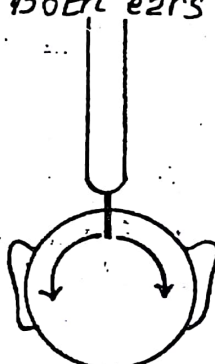
Tests of deafness

① Weber test

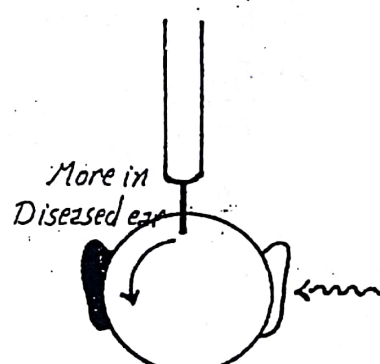
Base of Fork on Forehead
Both ears



More in Normal ear



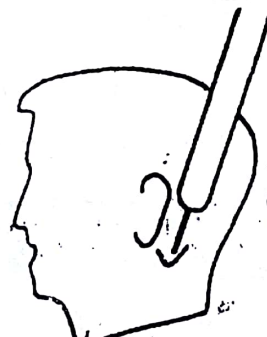
Normal
equal on both ears



More in Diseased ear
Conductive D.

② Rinne test

Base of fork on mastoid process
then next to ear.
One ear



Bone > Air
conduction

Conductive D.



Air > Bone
conduction

Normal

③ Audiometry: Graph as % of hearing loss

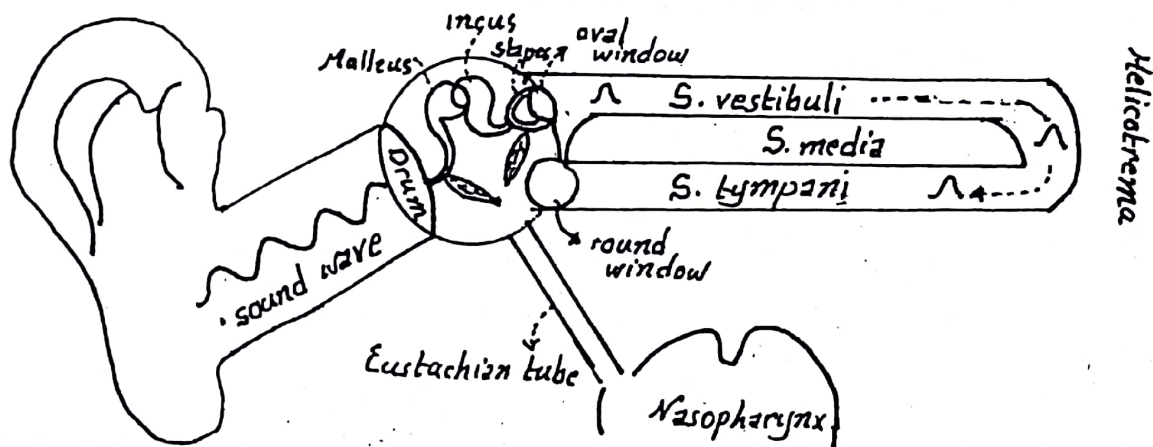
S.S.

(28)

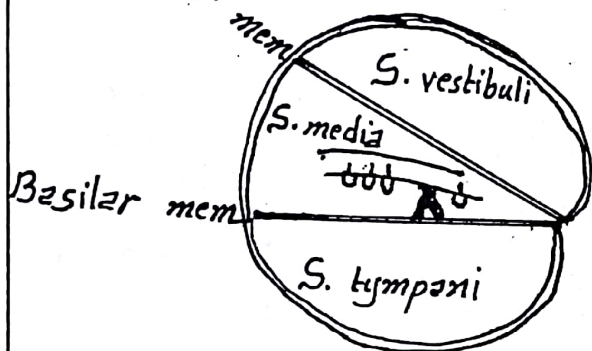
Tinnitus

ringing sensation in the ear
due to irritation of inner ear or pathway

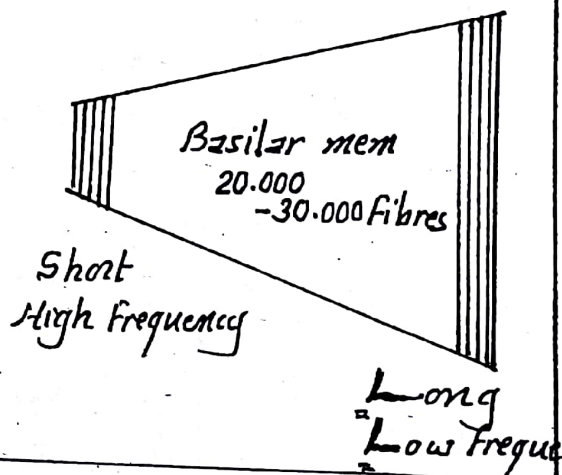
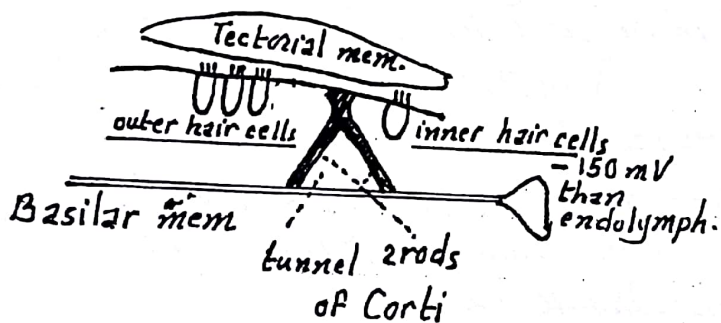
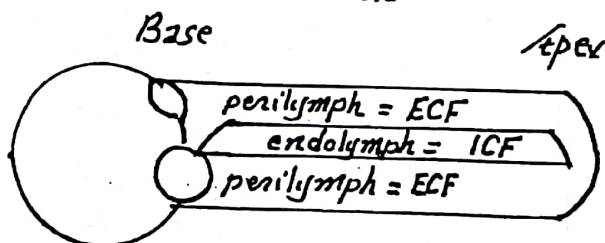
Hearing



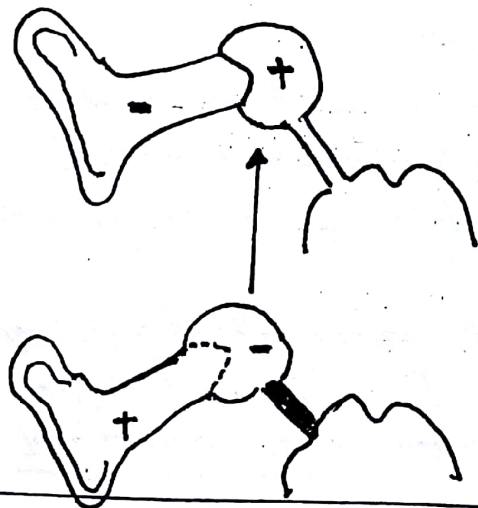
Cochlea



Cochlea



Eustachian tube



The Chemical Senses

Smell

Importances of olfaction:

- 1 determines the Flavour of food.
- 2 essential for gastro-intestinal functions.
- 3 avoids dangerous liquid & volatile substances
- 4 plays a role in sexual behaviour
- 5 triggers long term memories.

Olfactory mucosa & olfactory receptors

- Site 5 cm² on superior nasal concha
- Innervation Olfactory & trigeminal n
- 3 types of cells:
 1. Olfactory (receptor) cells bipolar cells life span 60 days
 2. Supporting cells columnar cells 6-12 cilia
 3. Basal cells form new receptors

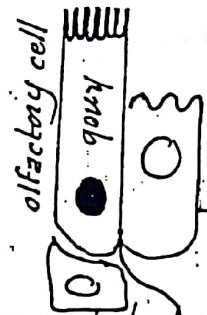
Properties of olfactory receptors

- 1 Sensitivity extremely sensitive
 - 2 Discrimination of odours High ability.
 - 3 Discrimination of intensity Low ability.
 - 4 Adaptation Very Rapid (Receptor or central adapt.)
 - 5 Specificity one receptor responds to many odours
 - 6 Adsorption to odorant molecules $\rightarrow$ receptor potential
 - 7 Amplitude of EOG $\propto$ intensity of the stimulus
- An odorous material should be
 - 1 Volatile
 - 2 H₂O soluble
 - 3 Lipid soluble
 - Stimulation of olfactory cells

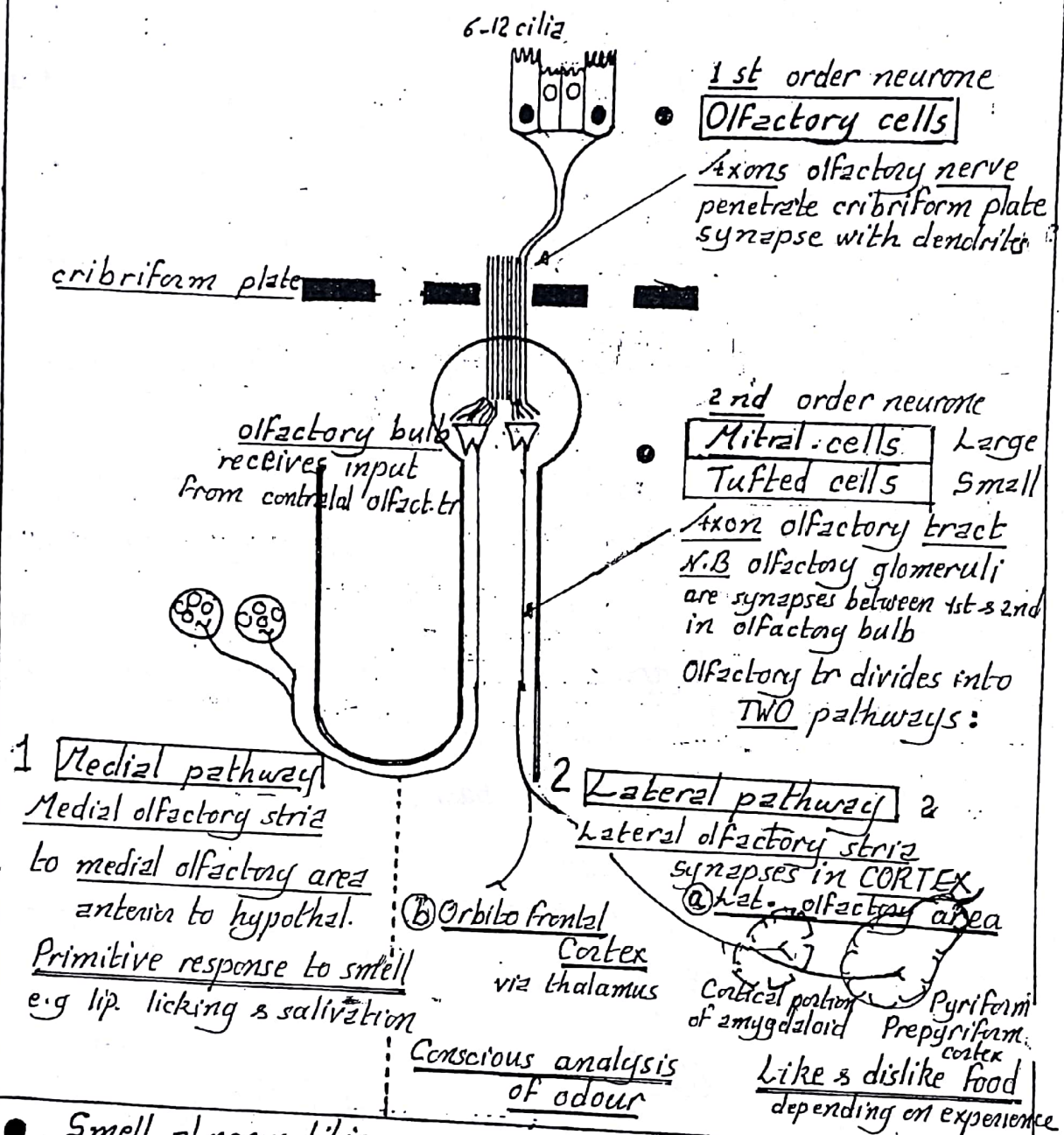
Odorant substance binds with receptor odorant binding ptn
 $\rightarrow$ activates G ptn $\rightarrow$ activates adenylyl cyclase
 $\rightarrow$ opening of Na⁺ channels $\rightarrow$ receptor potential

Test for smell:

Simple test: familiar non irritant substance
to avoid stimulation of trigeminal nerve
 $\rightarrow$ sneezing, lacrimation



Pathway of olfaction



● Smell abnormalities :

- 1 Anosmia : no smell
- 2 Hyposmia : -- smell
- 3 Dysosmia : Distorted smell

● Olfactory mucosa is not directly exposed to flow of inspired air.

- Olfactory " is distinguished from surrounding resp. mucosa
- 1 Presence of Bowman's glands
 - 2 Presence of yellowish Brown pigment secreted by Bowman's glands
 - 3 Absence of rhythmic ciliary beating.

Taste

Taste buds and taste receptors

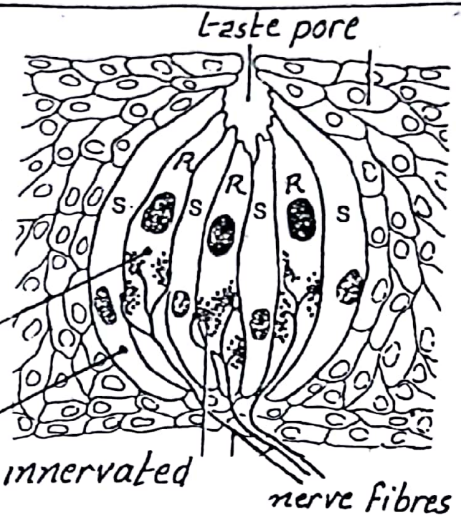
- Structure: Gustatory papillae contains

Taste buds which are collection of

- 40-60 taste cells connected to gustatory r. endings

- numerous supporting cells ← not innervated

It has a taste pore



- Distribution: tongue, palate, epiglottis and pharynx.

- Specialisation:

At low conc., each taste bud responds to 1 of 4 primary taste stimuli.

At high conc., most taste buds respond to more than one stimulus.

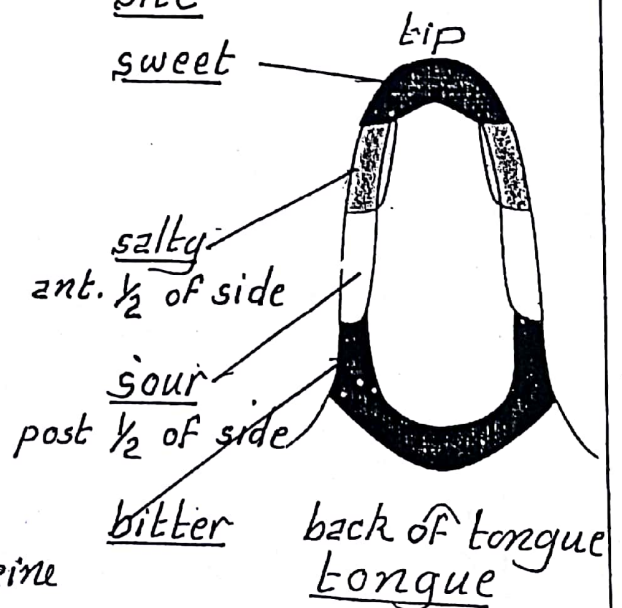
- Regeneration: cycle takes few days

New taste buds arise from the supporting epithelial cells

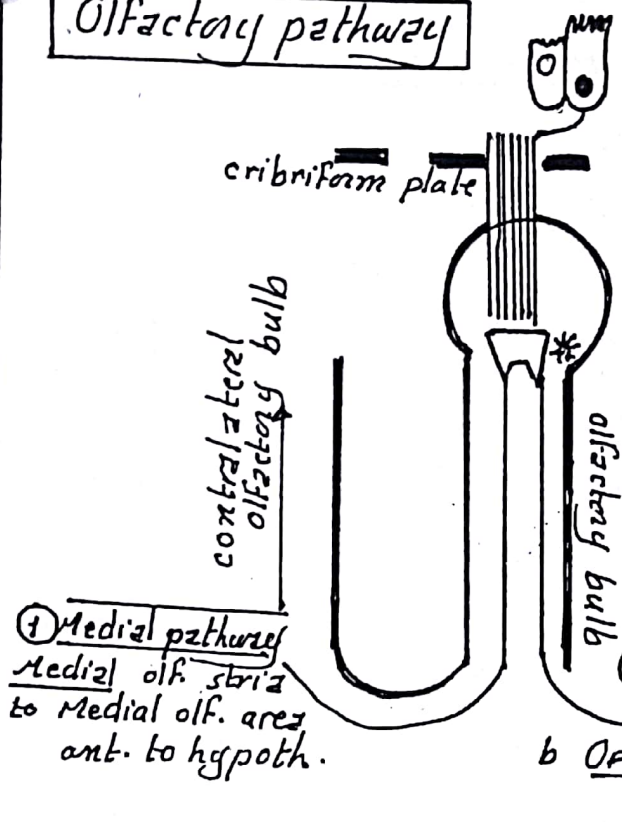
Contact with different neurone converts epith cells to taste cells

- Taste modalities: 4 basic taste modalities

<u>Type</u>	<u>Tested by</u>	<u>Site</u>
1 <u>Sweet</u>	<u>organic molecules</u> eg sugar, glycerol s... hydres	<u>sweet</u>
2 <u>Salty</u>	<u>NaCl</u>	<u>salty</u> ant. 1/2 of side
3 <u>Sour</u>	<u>H⁺ of acids</u>	<u>sour</u> post 1/2 of side
4 <u>Bitter</u>	<u>Alkaloids</u> eg quinine & caffeine	<u>bitter</u> back of tongue



Olfactory pathway



Receptor (cilia: 6-12) o
s 1st order neurone

Olfactory cells

Axon olfactory nerve
penetrate cribriform plate
excellent spatial summation

2nd order neurone

Mitral & tufted cells

Large small
Axon olfactory tract
Olf. glomeruli synapse between 1st
tract 2 pathways
Medial & Lateral

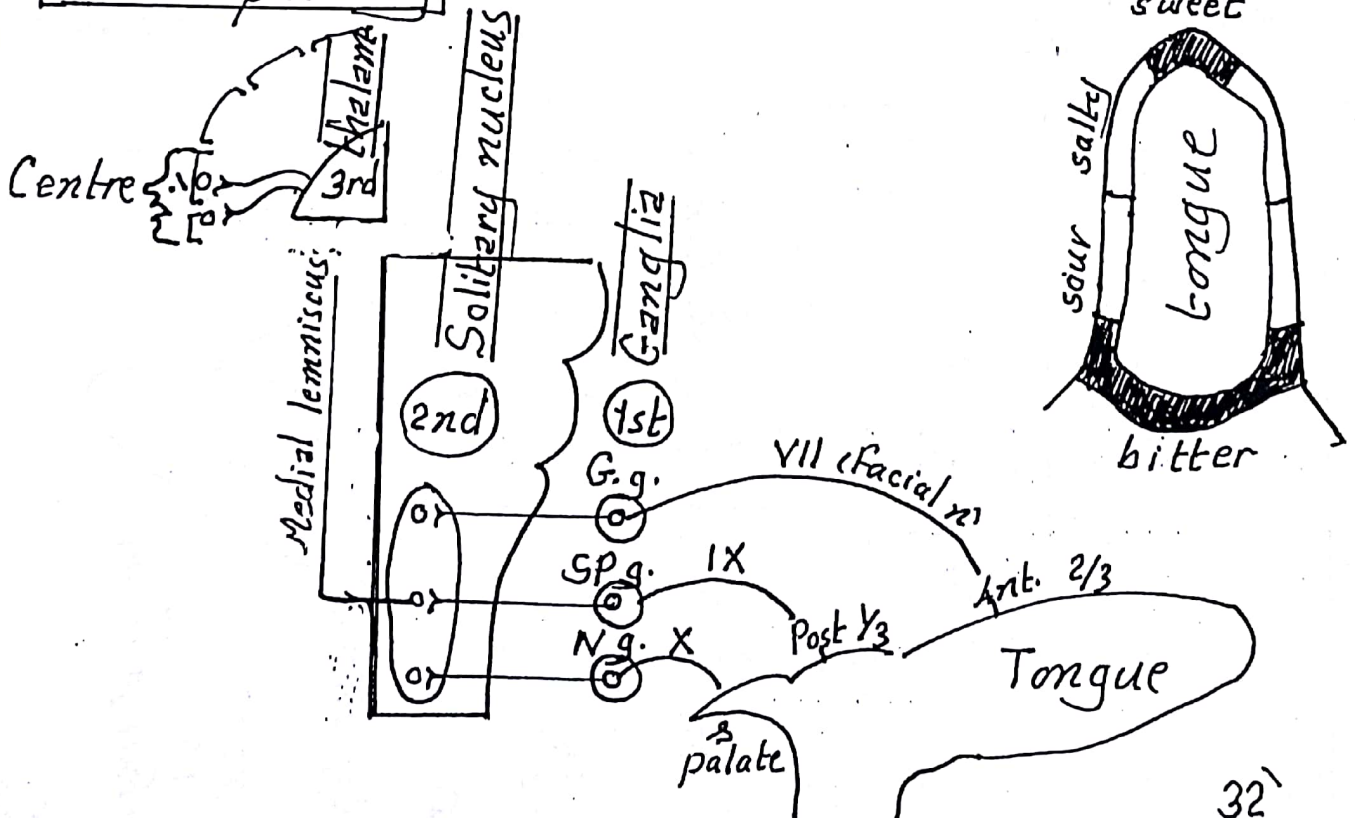
② Lat. pathway " 2 Lat olfactory stria"
synapse in cortex
a Lat olf area
Amygdaloid & Piriform cortex

Primitive response to smell
e.g lip licking & salivation

Conscious analysis
of odour

Like & Dislike
depending on past experience

Taste pathway



Mechanism of stimulation of taste receptors:

1st Tasted substance is dissolved in saliva.

Tasted substance

Taste receptors are depolarised by:

1 Sweet

Opening of Na^+ channels

Closing of K^+ channels via cAMP

2 Salty

Opening of Na^+ channels

3 Sour

Closing of K^+ channels via $++$ intercell. $[\text{H}^+]$

4 Bitter

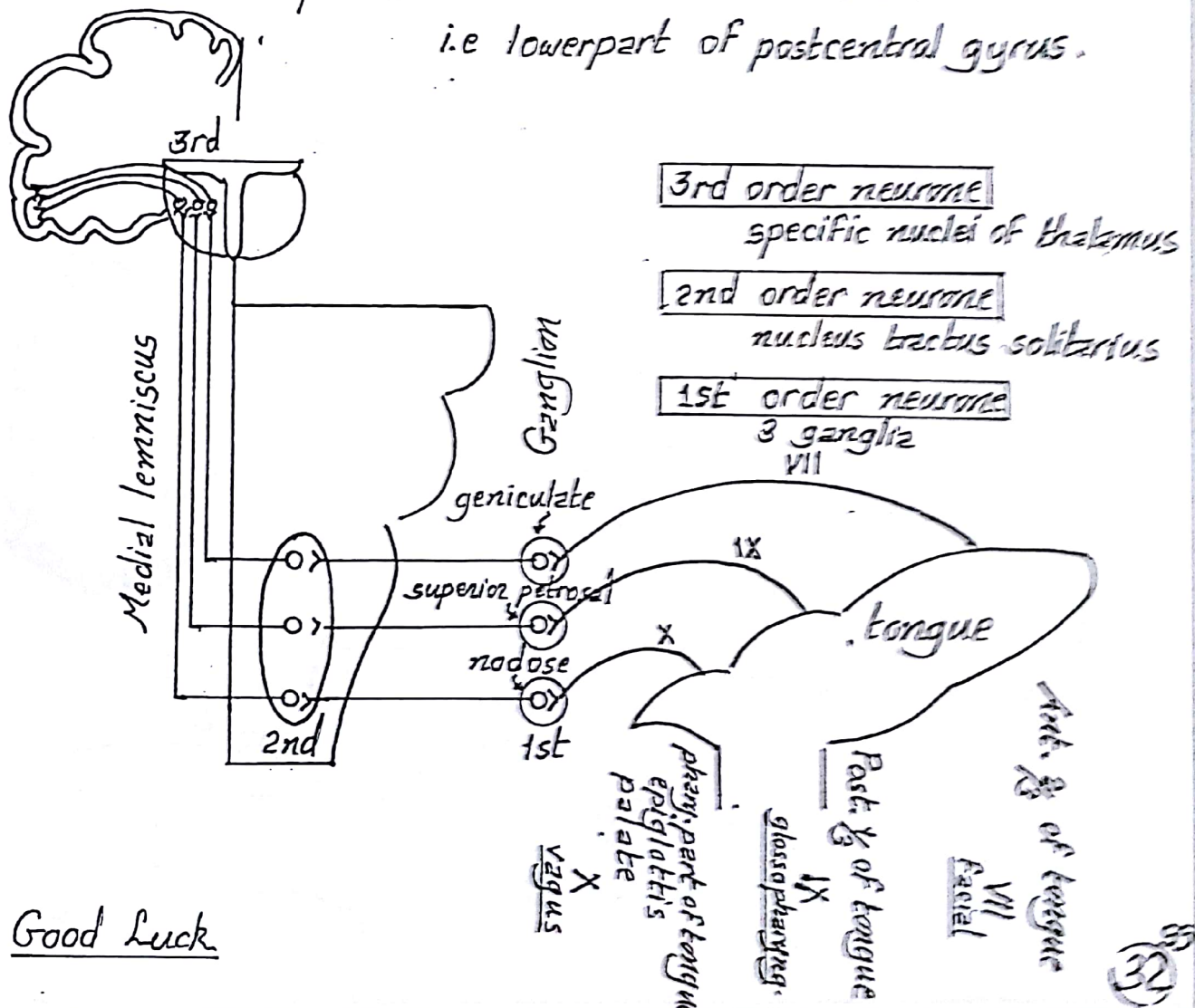
Activation of gustatory nerves occurs by:

$++ \text{IP}_3 \rightarrow ++ \text{Ca}^{++} \rightarrow ++$ release of ch. transmitter

Taste pathway:

Centre nonspecific

Area subserves cutaneous face sensations
i.e. lower part of postcentral gyrus.



Good Luck

SPECIAL SENSES

Special sense organs have receptors characterized by being:

- Protected by bone cavity,
- Present in head, so information reaches the brain rapidly.
- Distant receptors except taste receptors.

VISION

PHYSIOLOGIC ANATOMY OF THE EYE: 3 LAYERS AND 3 CONTENTS:

3 layers:

1) Outer fibrous coat consists of:

1- Cornea:

Anterior transparent 1/6 of the outer coat.

2- Sclera:

Posterior 5/6 of the outer coat.

It is the hardest part of the eye.

It is covered anteriorly by the conjunctiva.

The anterior margin of the sclera fuses with the cornea at the corneo-scleral junction.

2) Middle coat i.e. uveal tract, consists of:

1- Choroid:

Posterior 5/6 of the middle coat.

It is vascular and rich in melanin.

2- Ciliary body:

Anterior ring, which contains the ciliary muscle, ciliary processes and suspensory ligaments.

3- Iris:

Pigmented perforated disc, the hole is the pupil.

It contains pupilloconstrictor and pupillodilator muscles.

3) Inner nervous coat: Retina

- It is formed of ten layers and contains the rods and the cones.

- Macula lutea and fovea centralis:

The macula is a yellowish spot less than 1mm^2 located 3mm from the temporal side of the optic disc opposite to the posterior pole of the eye;

Fovea centralis is the central portion of the macula 0.4mm in diameter. It is composed of densely packed thin cones.

- The optic disc (blind spot): it is the site of exit of optic nerve, 1.5 mm in diameter located 3 mm from the nasal side of the macula lutea.

3 Contents:

1- Lens attached to ciliary body by suspensory ligaments.

- 2- Aqueous humour in front of lens
 - 3- Vitreous humour behind the lens
- Fluid system of the eye.
 Vitreous humour is highly viscid (albumin & hyaluronic acid).
 It supports the retina and supplies it with glucose.
 It has a refractive index 1.34

Notes:

- Anterior pole is the center of anterior curvature of the eyeball.
 - Posterior pole is the center of the surface of the eye.
 - Optic axis is the line joining the 2 poles.
 - Visual axis is the line that passes from the fovea centralis via the nodal point of the eye to the fixation point.
- It is the axis along which the eye is directed.

LIGHT WAVES

- Light is the visible portion (400-700nm = 4000-7000 angstrom) of the electromagnetic radiation

Electromagnetic radiation ranges from radio waves (long wavelength) to x-ray (very short wave length).

- Light consists of tiny particles (photons), which have wave like properties and travel in straight lines.

- Velocity of any wave = its wavelength x its wave frequency.

Wave frequency = the number of wave peaks or cycles that passes a point in a given period of time & is expressed in cycles per second or Hertz.

Wave length = distance between 2 successive wave peaks

Velocity of light in air, gases and vacuum = 300.000 km/s, but it travels at a slower rate in transparent solids or liquids.

- Invisible light:

Ultraviolet darkens the skin and kills bacteria.

However, it may cause skin burning and skin cancer.

Infrared radiation has heating effect on the body.

- Lasers is very strong monochromatic (one wavelength) light.

It gives concentrated heat, which is used in fine surgery & industry.

OPTICS OF THE EYE

When light rays strike an object, they may be:

- 1- Absorbed and changed into thermos forms of energy e.g. heat.
- 2- Reflected on smooth regular surface e.g. mirror.
- 3- Refracted.

Refraction depends on:

- 1- The refractive index of the media:

$$RI = \frac{\text{Velocity of light rays in air}}{\text{Velocity of light rays in media}}$$

RI of the aqueous humour = 1.33

RI of cornea = 1.38

RI of the vitreous humour = 1.34

RI of lens = 1.4

2- The interface

A- Plane interface:

If light rays strike it:

- Perpendicularly to the surface, they are not bent.
- Forming an angle (if light rays passing from air to a denser medium) they will be refracted towards the perpendicular line and vice versa.

B- Convex spherical lens:

- Light rays passing through the nodal point (center of the lens) undergo no refraction.
- Parallel rays converge on a point i.e. focal point.
- Focal length is the distance between focal & nodal points.
- When diverging rays pass through a convex lens, the rays converge on a point at a distance longer than the focal length.
- Divergent lenses can not form an image.

N.B. Cylindrical lenses (unlike spherical lenses) have a refractive power only in one plane i.e. parallel rays are focused on a line and not a point.

$$\text{Refractive power (in diopters)} = \frac{1}{\text{Focal length in meter}}$$

Lens formula:

$$\frac{1}{\text{Object distance}} + \frac{1}{\text{Image distance}} = \frac{1}{\text{focal length}}$$

Image size:

$$\frac{\text{Image distance}}{\text{Object distance}} = \frac{\text{Image size}}{\text{Object size}}$$

The application of the lens formula to non accommodating eye:

- Object distance is infinity.
- Image distance: from nodal point of the eye to retina = 1.5 mm.
- Diopteric power of the resting eye = $1/\alpha + 1/0.015 = 67 \text{ D}$.

Characteristics of retinal image:

- 1- Sharp well defined if it is accurately focused on retina.
- 2- Reversed and inverted.
- 3- Size depends on the angle, by which the objects subtend to the eye.

The visual cortex corrects such image.

PROTECTIVE MECHANISMS OF THE EYE:

- 1- The strong bony orbit protects the posterior 2/3.
- 2- The eyelids protect the anterior 1/3.
- 3- The tear film moistens & protects the cornea and conjunctiva.

4- Closure of eye lids:

Types of closure of eye lids:

A) Blinking i.e. rapid closure of the eye lids

1) Reflex blinking (protective blinking) as a result of:

i- Tactile stimulation e.g. corneal irritation (corneal reflex), conjunctival or ciliary (eyelashes) touch.

ii- Optic stimulation

- Dazzle reflex: shining bright light in the eye.

- Menace reflex: moving object coming very close to eye.

iii- Auditory stimulation, e.g. sudden loud sound (auriculo-palpebral reflex).

2) Spontaneous blinking

- 10-12 times/minute, more in women.

- Duration: 0.3 second, so it does not interfere with vision.

- Increased by emotions, air current & conjunctival irritation.

- It can occur in a blind person.

3) Voluntary blinking.

B) Voluntary winking: forced closure of one eye (usually left).

C) Blepharo-spasm: forced contraction of eyelids in response to eye injury.

5- The eye lids cover the eye during sleep.

THE EYE LID

- Structure:

Skin, muscle (orbicularis oculi), tarsus and posterior conjunctival mucous membrane.

- The upper eyelid is raised by:

One) Levator palpebrae superioris (skeletal muscle) supplied by oculomotor nerve.

Two) Muller's muscle (smooth muscle) supplied by sympathetic.

- Functions of eye lid movements:

- 1- Regulation of the amount of light entering the eye.
- 2- Protection from excessive illumination and foreign bodies.
- 3- Distribution of tears & their conduction to the nose.

LACRIMAL APPARATUS & TEARS

1- Secretory part:

Lacrimal gland supplied by parasympathetic (facial fibers).

2- Excretory part:

Lacrimal puncta → lacrimal canaliculi → lacrimal sac → naso lacrimal duct.

Tears are isotonic solution pH 7.4, RI 1.33

Tears contain NaCl, NaHCO_3 , glucose & protein.

Precorneal film of tears is formed of:

	%	Secreted by:
1- Lipid	1%	Meibomian glands
2- Water	90%	lacrimal glands
3- Mucin	rest	conjunctiva

Tears film has the following functions:

- 1- It maintains optical uniform corneal surface by filling inequalities of epithelium.
- 2- **Corneal nutrition:** It is a medium for gas exchange.
- 3- **Protection:** It contains Lysozymes, lactoferrin & IgG, IgM, IgA.
- 4- **Lubrication:** It facilitates eyelid movement.

REFRACTIVE MEDIA OF THE EYE:

Light passes through 4 refractive interfaces:

- i) The anterior surface of the cornea.
- ii) The posterior surface of the cornea.
- iii) The anterior surface of the lens.
- iv) The posterior surface of the lens.

CORNEA

Functions

1- The resting eye has an optical power 67D.

- Most of the optical power (2/3) is in the cornea (42 to 45D) and fixed

This is because the cornea has:

One) **High degree of curvature** and its diameter is 11mm.

Two) High refractive index 1.38 which is nearly equal to that of aqueous humour 1.33 (air has RI= 1).

2- The cornea protects the delicate inner structure of the eye.

Corneal reflex (Superficial reflex)

- Stimulus: Touching the cornea of one eye by a foreign body.
- Receptors: Free nerve endings (only type of receptors in cornea).
- Afferent: Ophthalmic division of the trigeminal nerve.
- Center: Superior colliculus & pons.
- Efferent: Facial nerve.
- Response: Bilateral blinking.

It is used to test the integrity of the 5th & 7th nerve and to know the depth of anaesthesia.

Causes of corneal transparency:

1- The cornea is avascular

It obtains its oxygen from tears & aqueous humour.

It obtains its nutrients from aqueous humour.

2- The cornea is supplied by unmyelinated nerve endings only.

3- Corneal specific structure

- Uniform in diameter.
- Parallel to each other and to the surface of the cornea.
- Regular spacing between fibrils (which is less than the light wavelength).

4- Corneal dehydration

If hydration occurs → corneal cloudiness as H₂O interferes with arrangement of the fibers.

Corneal dehydration is caused by:

- i- Metabolic pump: Inner epithelial layer of the cornea has Na-K pump which pumps Na⁺ into aqueous humour.
- ii- Osmosis: The high Na⁺ content of aqueous humour causes outward movement of H₂O from the cornea.

Note:

Corneal opacities are treated with corneal graft.

The absence of vascular supply prevents the immune response.

AQUEOUS HUMOUR

Definition:

It is an alkaline clear water fluid that fills the anterior and posterior chambers.

Mechanism of formation:

It is actively secreted by the epithelium lining the ciliary processes.

1) 1st active transport of Na^+ ions through Na / K ATPase pump followed by passive diffusion of chloride and bicarbonate ions (HCO_3^- is formed by the action of carbonic anhydrase enzyme), H_2O follows by osmosis.

2) Several nutrients as amino acids, ascorbic acid & glucose are transported across the epithelium by active transport or facilitated diffusion.

Aqueous humour is continuously formed and reabsorbed at an average rate of 2-3 microliters each minute.

Outflow of aqueous humour from the eye:

From posterior chamber through the pupil to the anterior chamber then, to irido-corneal angle, where it is drained through: a trabecular meshwork called spaces of Fontana to canal of Schlemm to the aqueous episcleral veins.

Functions of the aqueous humour:

- 1- It supplies nutrients & oxygen to the cornea & lens.
- 2- It drains metabolites of surrounding tissues.
- 3- It is one of the optical media of the eye.
- 4- It maintains the intraocular pressure (IOP) to keep the shape of the eye.

INTRAOCULAR PRESSURE: (IOP)

Measurement:

By tonometer or digital method.

Normal standard:

12-20 mmHg.

It shows diurnal variation, highest in the morning & lowest in the evening.

Regulation:

Mainly by regulation of aqueous outflow e.g. if the IOP rises, the rate of fluid flow into the canal of Schlemm increases as the spaces of Fontana are distended. Thus, the IOP returns to its normal level.

Functions of the IOP:

- 1) The IOP is important for the normal focusing mechanism of the eye as it maintains lens flattened during rest by:
 - A stretching force on the lens ligaments.
 - A pressure flattening force on the lens surface.
- 2) It maintains the spheroid shape of the eye.

GLUCOMA

Definition:

++ IOP above normal i.e. more than 21 mmHg.

Cause:

Increased resistance to fluid outflow through the trabecular spaces.

Effects:

1) Glucoma is one of the most common causes of blindness due to compression of the optic nerve & retinal artery → retinal atrophy.

2) Failure to accommodate to near vision.

3) Severe pain (headache).

Treatment:

1) --- formation of aqueous by diamox (carbonic anhydrase inhibitor).

2) ++ drainage of aqueous by pilocarpine (pupilloconstrictor).

3) Surgical treatment to open the spaces of the trabeculae to allow increased outflow of aqueous humour.

LENS

Structure:

- The lens is enclosed in an elastic capsule.

- The posterior surface of the lens is more convex than anterior surface during rest.

- The younger fibers constitute lens cortex & the old ones constitute the lens nucleus.

- H₂O 65% & proteins 35% of lens weight.

Metabolism:

- The lens has a low metabolic rate.

- Energy is derived from oxidation of glucose mainly anaerobically.

Some aerobic metabolism also occurs through the presence of glutathione.

The transparency of the lens is due to:

1) It is avascular & obtains its oxygen & nutrients from the aqueous humour.

2) It has no nerve supply.

3) The lens fibers are uniformly arranged & densely packed so that a distance between fibers is less than the light wavelength.

4) Various lens constituents have almost the same refractive indices.

- Lens constitutes 1/3 of the total refractive power of the eye optical system during rest, (20 diopter during rest).

- 34 diopter during full accommodation.

- RI 1.42

CATARACT

- It is partial or complete loss of lens transparency

- It is a degenerative condition due to:

1) Decreased glutathione (antioxidant) → accumulated oxygen

radicals which change the membrane permeability to water & ions as in senile cataract.

2) Coagulation of lens proteins with deposition of calcium salts.

- Cataract is common in old age (senile cataract), diabetes mellitus, and excessive exposure to ultraviolet rays or temperature.

- Cataract is treated by surgical removal of entire lens & replacing it by a powerful convex lens in front of the eye or artificial implanted lens inside the eye.

ACCOMMODATION

Definition:

It is the changes that occur in the lens to see near objects.

Mechanism of accommodation:

- In order to bring the image of the near object to focus on the retina, the eye lens increases its dioptric power by increasing its curvature (accommodation).

- Under resting condition of the eye:

The constant tension of zonular fibers (suspensory ligaments) causes the lens to remain relatively flat.

- During near vision:

The ciliary muscles contract:

* The radial muscle fibers when contract → the peripheral insertion of lens ligaments are pulled forward → releasing the tension on the lens.

* The circular fibers when contract → reducing the pull of the ligaments on the lens capsule. Thus, the lens becomes more spherical & its convexity increases (radius of lens curvature becomes 5.5 mm instead of 10 mm). So its dioptric power increases, which brings the image of the near object on the retina.

Accommodation occurs mainly in the anterior surface of the lens.

This can be proved by:

Power of accommodation:

It decreases with age as the elasticity of the lens decreases.

It is about 14 D at age of 10 years.

10 D at 20 years.

2 D at 50 years:

Only one D at age of 60 years.

Near point:(maximal accommodation)

10 cm in young adult.

80 cm at the age of 60 years.

Far point:(without accommodation)

6 meters or more.

Range of accommodation:

It is the distance between far & near points.

The range of accommodation decreases with age.

NEAR RESPONSE (NEAR REFLEX)

Definition:

Eye changes, which occur when the person looks at near object.

Mechanism:

1) Accommodation i.e. ++ dioptric power of the eye lens.

Mechanism of accommodation: **involuntary** (discuss).

2) Meiosis i.e. pupilloconstriction: **involuntary**

- To -- the amount of light entering the eye.

- To ++ the lens depth of focus.

3) Convergence of both eyes : **voluntary**

To allow the 2 images to fall on 2 corresponding points in both eyes to prevent diplopia (double vision).

Nervous pathway:

Afferent: Visual pathway to area 17, 18 & 19 in occipital cortex.

Center: Midbrain (superior colliculus).

Efferent: Oculomotor nerve

One- Parasympathetic part: produces accommodation & meiosis.

Nucleus: Edinger Westphal nucleus.

Preganglionic long fibers.

Ganglion: Ciliary ganglion.

Postganglionic short ciliary nerve.

Two- Somatic part: produces convergence.

N.B. Parasympatholytic drugs e.g. atropine paralyse accommodation (cycloplegia) & produce pupillodilatation.

ERRORS OF REFRACTION

1- Presbyopia:

Definition:

Weak accommodation by aging.

The power of accommodation decreases from 14 D in young child to 2 D at age of 50 years to zero at age of 70 years.

Cause:

-- elasticity of lens capsule due to protein denaturation.

Optical changes in presbyopia:

- The far point does not change.
- The near point recedes away from the eye.
- The range of accommodation undergoes progressive diminution.

Treatment:

Convex lens for near vision only.

Items	2- Myopia	3- Hyperopia = Hypermetropia
- Eye ball Absolute Relative	(Short sightness) Abnormally long eye ++ curvature of lens, cornea In front of retina	(Far sightness) Abnormally short eye -- curvature (power) of cornea Behind the retina
- Parallel rays converge	Divergence	Convergence
- Person needs more	Divergent lens	Convergent lens
- Treated with	(Biconcave lens)	(Biconvex lens)
- Near point	Less than 10 cm	More than 10 cm
- Far point	Less than 6 meters	Normal
- Accommodation	Aggravates the condition.	Essential for near & far vision → headache

4- Astigmatism (no point focus)

Cause:

Inequality of corneal curvatures or less commonly the lens curvatures in various planes.

It may be myopic, hypermetropic or both.

Effect:

A point is seen as a line & a line appears to have a halo on either side.

Treatment:

A cylindrical lens put with its curvature in the plane of error.

IRIS

- It is a disc shaped continuation of uveal coat anteriorly.

- It is the colored part of the eye.

Its different colours are due to the different degree of melanin pigments in the iris.

- It is perforated near its center by the pupil (1.5 mm to 8 mm).

Anatomy:

	Pupilloconstrictor muscle	Pupillodilator muscle
Muscle Fibers	Circular	Radial
Nerve supply	Parasympathetic Nucleus: Edinger Westphal Nucleus in midbrain	Sympathetic Hypothalamus → LHCs of upper 2 thoracic
Ganglion	Ciliary ganglion	Superior cervical
Nerve	Short ciliary nerve	
Tone	Strong (dominant)	weak

Functions of iris:

1- The iris pigment restricts the passage of light rays to the pupil.

2- It regulates the amount of light falling to the retina.

3- It prevents light passage through the peripheral parts of the lens.

Thus, it prevents spherical & chromatic aberrations:

i) **Spherical aberration:** The peripheral parts of lens have greater refractive power (more curvature) → different refraction → different focus.

ii) **Chromatic aberration:** The peripheral part of lens acts as a prism, which analyses the white light into its spectral components.

The eye compensated for spherical & chromatic aberration by:

One- The small size of the pupil that cuts off light rays from lens periphery.

Two- The periphery of lens has a refractive index 1.38 less than the center 1.42.

4- Constriction of pupil increases the depth of focus.

The depth of focus is the maximal distance, along which an object can be moved without blurring of its image, while lens power is constant.

The depth of focus varies inversely with the size of pupil.

LIGHT REFLEX

Definition:

Exposure of one eye to light results in reflex constriction of both pupils i.e. 2 components:

a- Direct constriction of the stimulated eye.

b- Indirect or consensual constriction of the unstimulated eye.

N.B. Pupillodilatation, which occurs when light intensity is diminished, is slower process than pupilloconstriction with light.

Nervous pathway:

Afferent: optic nerve, optic chiasma, optic tract but no relay in thalamus (lateral geniculate body).

Center: midbrain (pretectal nucleus).

Efferent: oculomotor parasympathetic division on both sides (discuss).

Consensual light reflex is caused by:

- 1- Decussation at the optic chiasma.
- 2- Bilateral innervation of the Edinger-Westphal nucleus from pretectal nucleus in the midbrain.

Argyl – Robertson pupil:

Cause:

Lesion in the pretectal region on both sides due to neurosyphilis.

Effect:

The pupil does not constrict with the light reflex but constricts with accommodation reflex.

CAUSES OF MIOSIS & MYDRIASIS

Meiosis	Mydriasis
1-light adaptation 2- Near vision (accommodation reflex) 3-Sleep 4- Horner's syndrome 5- 3 rd stage of general anesthesia 6- <u>Orbicularis (lid closure) reflex</u> : Forcible closure of lids results in meiosis of same eye. 7- <u>Pontine haemorrhage</u> : due to sympathetic lesion	1- Dark adaptation 2- Far vision 3- Emotion, fear, pain & asphxia 4- Lesion in oculomotor nerve or its nucleus 5- 2 nd stage of general anesthesia: Pupil dilated & reactive to light. 4 th stage; pupil dilated & fixed and no corneal reflex. 6- <u>Cilio-Spinal reflex</u> : Stimulation of skin of the neck results in mydriasis. 7- <u>Glucoma</u> i.e. ++ intraocular pressure.
<u>Drugs</u> - <u>Parasympathomimetics</u> e.g. pilocarpine & eserine - <u>Morphine poisoning</u> - <u>Histamine</u>	<u>Drugs</u> - <u>Parasympatholytics</u> e.g. atropine <u>Passive</u> mydriasis - <u>Sympathomimetics</u> e.g. adrenaline <u>Active</u> mydriasis - <u>Alcohol</u> intoxication - <u>Cocaine</u> sensitizes the dilator pupillae ms to epinephrine.

FUNCTIONS OF THE CHOROID

- 1- It provides blood supply to the eye (highly vascular).
- 2- It prevents reflection of light rays inside the eye (rich in melanin).
- 3- It gives attachment to the ciliary muscle.

RETINA

The retina is formed of 10 layers from outside to inside:

- 1) Pigment layer.
- 2) Layer of photoreceptors (rods & cones) i.e. cellular layer.
- 3) Outer limiting membrane.
- 4) Outer nuclear layer (cellular layer).
- 5) Outer plexiform layer
(Synaptic layer between photoreceptors & horizontal & bipolar cells)
- 6) Inner nuclear layer (cellular layer).
- 7) Inner plexiform layer
(Synaptic layer between ganglion cells & bipolar cells & amacrine cells)
- 8) Ganglion cell layer (cellular layer).
- 9) Layer of optic nerve fibers.
- 10) Inner limiting membrane.

Foveal vision is sharp & acute i.e. visual acuity is highest because:

- 1) Light falls on the receptors (cones) directly:

it is caused by :

i- All other layers of retina are displaced to the side.

ii- Cones are not covered by blood vessels.

- 2) In the fovea, each cone is connected to a single bipolar cell & single ganglion cell giving a single optic nerve fiber to the brain (no convergence).

- 3) The pigmented epithelium layer is highly developed in the fovea.

Surrounding the fovea, rods gradually appear & predominate while cones decrease.

N.B The retinal vessels supply the bipolar & ganglion cells, but photoreceptors are nourished by capillary plexus in the choroid.

Thus, retinal detachment is damaging to the receptors.

-The pigment layer of the retina:

Single layer of cells that contain melanin in a direct contact with choroid.

Functions:

- 1) Outer nuclear layer containing the nuclei of photoreceptors.
- 2) Inner nuclear layer contains the nuclei of bipolar, horizontal & amacrine cells.
- 3) Ganglion cell layer is the third cellular layer.
Their dendrites receive inputs from bipolar cells.
Their axons pass to the optic disc & form the optic nerve.

Horizontal cells	Amacrine cells
- They are inhibitory cells that secrete GABA (inhibitory chemical transmitter) - They are stimulated by rods & cones - Their axons synapse with the dendrites of bipolar cells & axon terminals of rods & cones located laterally - Function: inhibit rods & cones (lateral inhibition) as well as bipolar cells	- They are excitatory cells that secrete excitatory chemical transmitter - They are stimulated by bipolar cells - They adapt very rapidly i.e. they respond very strongly at 1st then the signal dies in a fraction of a second - Functions: 1) They excite the ganglion cells 2) They indicate sudden changes in light intensity & detection of moving objects

Characteristics of rods & cones (photoreceptors):

Each rod & cone consists of four functional segments:

- 1) Outer segment: Rod like in rods & conical in cones.

-It contains 1000 discs containing the photosensitive pigments which constitute 40% of the entire mass of outer segment.

-Discs are folded shelves of membrane in cones but are separated from the membrane in rods.

-Discs are continuously formed at the base of outer segment & migrate towards the apex, where they are sloughed off.

- 2) Inner segment: contains abundant mitochondria.

- 3) Nucleus

- 4) Synaptic body: area of junction with other retinal cells.

	Rods	Cones
<u>Anatomical</u>		
1- Number	120 million in each retina	6 million in each retina.
2- Site	Mainly at periphery of retina. Absent in the fovea.	Central part of retina. Fovea centralis contains only cones. Few in the periphery.
3- photo-sensitive pigment	One type of rhodopsin (Scotopsin).	3 types of photopsin for blue, red & green colours.
4- Convergence	200 rods converge on a single bipolar cell & many bipolar cells converge on one ganglion cell.	In fovea, one cone is connected to one ganglion cell.
<u>Functional</u>		
1- Light sensitivity	Very high i.e. low threshold of stimulation.	Very low i.e. high threshold of stimulation.
2- Visual acuity	Very Low	Very high.
3- Colour perception	No	Responsible for colour vision.
4- Vision	Responsible for scotopic vision (dim night vision)	Responsible for photopic (day) vision.

DUPPLICITY THEORY OF VISION (VON KRIES THEORY):

There are 2 separate mechanisms of vision:

1- Photopic vision

It is vision in bright light (day vision).

It is the function of cones.

Details, boundaries & colours can be detected.

2- Scotopic vision

It is vision in dim light (dark vision).

It is the function of rods.

Details, boundaries & colours can not be detected.

N.B Star can be seen only if star image is fixed on the rod (not on fovea).

SPECTRAL SENSITIVITY OF PHOTOPIGMENTS:

Purkinje shift phenomenon:

It is the shift from cone (photopic) to rod (scotopic) vision.

1- During photopic vision:

The different wavelengths of the spectrum are perceived as different colours.

The yellow part (550 nm) appears most luminous.

2- During scotopic vision (reduced illumination):

All wavelengths appear as shade of gray.

Red is not seen at all.

The green blue part (505 nm) appears most luminous.

N.B Red & blue flowers are almost equally bright during daytime, but as light fades blue flowers are seen clearly but the red flowers appear black.

PROVE OF DUPLICITY THEORY & PURKINJE

PHENOMENON:

1- Photopigment absorption curve :

a- Rhodopsin curve

Shows maximum absorption for the green-blue (500 nm) wavelength & reflects the red & the violet ends, which give it the purple colour.

b- Absorption curves for the 3 cone photopigments

Show maximum absorption at the wavelengths of blue, greens & red.

The yellow wavelength gives maximum additive response by the 3 pigments.

2- Bleaching sensitivity curve :

a- Rhodopsin curve

Shows maximum bleaching with the green-blue wavelength

b- The cone photopigments

Show curves similar to their absorption curves.

3- Retinal visibility curve:

a- During low light intensity (scotopic vision)

The least visual threshold occurs for the green (500 nm) wavelength.

b- During photopic vision

The least visual threshold occurs for the yellow (550 nm) wavelength.

PHOTORECEPTOR POTENTIALS & SIGNAL TRANSMISSION IN THE RETINA:

Light absorption by the photosensitive pigments in rods & cones triggers the development of the receptor potential (photo-transduction), which includes the following:

- a) Photochemical changes (Bleaching).
- b) Genesis of electrical response.
- c) The excitation cascade.
- d) Signal transmission in the retina.

A) PHOTOCHEMICAL CHANGES (BLEACHING):

Photopigments:

- Photoreceptors contain photopigments which absorb light in their outer segments.
- There are 4 different photopigments in the retina: one (rhodopsin) in the rods & one in each of the 3 different types of cones
- Each photopigment consists of 2 parts:

1) 11-cis retinal dehydre (vit A₁) = chromophore:

The light sensitive absorbing part

It has a curved configuration.

It is the same in each of the four photopigments

2) Opsin:

Carrier serpentine protein embedded in the disc membrane

Opsin part is different in each one of the 4 photopigments

- a. Scotopsin in rods.
- b. Photopsin (3 different types) in cones.

Bleaching:

It is the separation between Opsin & chromophore after the exposure of photopigment to light with the transformation of 11 cis retinal to all-trans retinal with straight configuration

- When rhodopsin is exposed to light, it immediately decomposes & a series of intermediate products are formed.
- The immediate product formed is bathorhodopsin, which is converted to lumirhodopsin then to metarhodopsin I then to metarhodopsin II, & finally separation of all trans retinal from opsin i.e. complete bleaching.
- The retinal is transformed from 11-cis retinal (curved shape) to all-trans retinal (straight shape), which is unable to combine with opsins.
- The 11-cis retinal passes through many compounds before all-trans, one of these is metarhodopsin II (activated rhodopsin), which excites electrical response of the rods & cones.

- The enzyme retinal isomerase returns the all-trans into 11-cis form; the latter can join with opsin to reform rhodopsin.
- These reactions are independent on light, proceeding equally well in light or darkness

Role of vitamin A in rhodopsin formation:

Vitamin A is important for synthesis of rhodopsin.

Some of all-trans retinal $\xrightarrow[\text{NADH}]{\text{reduction by alcohol dehydrogenase}}$ all-trans retinol (one form vit.A)

All-trans retinol $\xrightarrow{\text{isomerase enzyme}}$ 11 cis retinol.

11 cis retinol $\xrightarrow{\hspace{2cm}}$ 11 cis retinal.

Notes:

- The cones undergo the same chemical changes described.
- All reactions in the rhodopsin retinene cycle are independent on light except the conversion of 11-cis retinal into all trans retinol.
- Vitamin A present in rod cytoplasm & in pigment layer of the retina is available to supply new retinal when needed to form more rhodopsin.

Vitamin A deficiency leads to:

- 1- Failure of dark adaptation i.e. night blindness or nyctalopia.
- 2- Degeneration of the cones.
- 3- Prolonged deficiency causes degeneration of neural layers of the retina

Role of vitamin B in rhodopsin formation:

Nicotinamide is a part of the nicotinamide adenine dinucleotide (NAD) molecule that acts as a coenzyme in the interconversion of retinal & vitamin A in the rhodopsin cycle.

B) GENESIS OF ELECTRICAL RESPONSE IN THE RETINA:

Excitation of photoreceptors (photoreceptor potential):

During rest (Dark condition):

- The rod cells inner segment contains:
An active Na^+ pump that creates a negative intracellular potential.
(the same in cones).
- The rod cells outer segment contains:
 Na^+ channels proteins
cGMP maintains these channels in the open state.

- Na^+ pumped by the inner segment, leaks into the rod cells through the outer segment (dark current).
Thus rods & cones are depolarized & their resting membrane potential is low (- 40 mV).
- The low resting membrane potential allows continuous release of synaptic transmitter.

C) LINKAGE BETWEEN RHODOPSIN & Na^+ CHANNELS:

The excitation cascade (on light exposure):

- Photons activate rhodopsin.
- Activated rhodopsin (metarhodopsin II) activates many inactive transducin molecules (G ptn in the membrane of the discs).
- Transducin activates cGMP phosphodiesterase (the enzyme breaking cGMP).
- Decreased cGMP allows closure of outer segment Na^+ channels & Ca^{++} channels.
- Rod intracellular membrane potential becomes more negative. i.e. hyperpolarized (maximum - 70 mV).

Degree of hyperpolarization $\propto$ log intensity of light

- Hyperpolarization decreases release of the synaptic transmitter:

If the neurotransmitter is excitatory $\rightarrow$ hyperpolarization (inhibition)
response of bipolar cell to light

If the neurotransmitter is inhibitory $\rightarrow$ depolarization (excitation)
response of bipolar cell to light

Note:

Such cascade reactions amplify the effect of light signal & this explains the extreme sensitivity of rods to light that can respond to one photon.

- Receptor potential of rods lasts for a longer time than cones i.e. receptor potentials of rods summate more easily.
- The photoreceptor itself does not fire action potentials, but its signal is passed to other neurons in retina

On removal of light:

- Rhodopsin kinase inactivates of metarhodopsin II leading to resynthesis of cGMP.
- Decrease rod Ca^{++} level activates guanylate cyclase & inhibits the activated phosphodiesterase, which leads to generation of cGMP.

So, outer segment Na^+ channels reopen and the membrane potential - 40 mV is returned back.

D) SIGNAL TRANSMISSION IN THE RETINA:

- The electric response of retinal neurons is **generator potential** i.e. local graded potentials to allow graded conduction of signal strength.
- The conduction of visual signals occurs by electronic conduction **except** in the **ganglion cells & some amacrine cells**, which conduct signals as action potentials.

ORGANIZATION OF RECEPTIVE FIELDS OF GANGLIONIC CELLS:

- Each ganglion cell receives synaptic input from many bipolar cells.
- Each bipolar cell receives input from a number of receptors, which are organized into the **receptive field**.
- The receptive field is formed of a central core (center) & a surrounding annulus (surround)
- Center illumination produces different responses of ganglion cell than surround illumination because surround illumination inhibits central illumination via the inhibitory horizontal cells (lateral inhibition to sharpen the edges of the stimulus) → the response of ganglion cell is either depolarization (stimulation = ON) or hyperpolarization (inhibition = OFF) depending on the location of stimulation within that single receptive field

The receptive fields of ganglion cells are organized into two center-surround antagonistic regions:

a- In an on center - off surround receptive field

The ganglion cell is excited when light stimulates the receptors in the center of the field & inhibited when light stimulated the receptors in the periphery of the field.

b) In an off center-on surround receptive field, the reverse.

TYPES OF GANGLIONIC CELLS

M Magno cells	P Parvo cells
1- Large cells	1- Small cells
2- Large dendritic field	2- Small dendritic field.
3- Large receptive field	3- Small receptive field
4- High conduction velocity.	4- Slow conduction velocity.
5- Show transient discharge	5- Sustained discharge.
6- Involved in detection of movement & change in light intensity.	6- Involved in color vision, texture & fine details.

AUTOMATIC REGULATION OF RETINAL SENSITIVITY (RETINAL ADAPTATION):

Definition

It is ability of the retina to adjust its sensitivity to different light intensities e.g. increases its sensitivity during maximal dark adaptation 100.000 - 500.000 times.

	Dark adaptation	Light adaptation
<u>Definition</u>	++ <u>retinal sensitivity</u> to light i.e. decreased <u>retinal threshold</u> .	--- <u>retinal sensitivity</u> to light i.e. ++ <u>retinal threshold</u> .
<u>Mechanism</u>	<u>Regeneration</u> of photochemical pigments in rods & cones.	<u>Breakdown</u> of photochemical pigments in rods & cones.
<u>Time</u>	Reaches maximum in <u>30 minutes</u>	It takes <u>5 minutes</u> .
<u>Changes</u>	Regeneration of photopigments. Mydriasis ++ signal intensity in retinal neurons. ++ retinal sensitivity to light.	Breakdown of photopigments. Meiosis --- signal intensity in retinal neurons. --- retinal sensitivity to light.

There are 2 components to dark adaptation:

The rise of retinal sensitivity to light occurs in 2 stages:

1) Rapid & small rise (5 -10 minutes)

Caused by full loading of cones with photopigments.

2) Slow & greater rise (30 minutes)

Caused by full loading of rods with photopigment.

Note:

Visual threshold:

It is the minimum amount of light, which produces a sensation of light.

COLOUR VISION

Definition:

It is the ability of the retina to distinguish different wavelengths (colours).

It is the function of cones.

Characteristics of colours:

1) Hue:

It is the actual colour e.g. red or green.

2) Saturation :

It is a measure of the purity of the colour.

Addition of white to a given colour causes it to be less saturated.

3) Brightness (luminosity):

It is measured by number of photons emitted per unit area per second.

4) Primary colours:

Red, green & blue.

5) Complementary colours:

Colours when mixed properly produce a sensation of white.

Yellow is complementary for blue.

Red is complementary for green.

- Mixing light of different wave lengths differs from mixing pigments
e.g. a mixture of blue & yellow pigments gives a green colour while
mixing blue & yellow lights produces sensation of white.

- The normal eye can distinguish the 7 colours of the spectrum & about
different 100 intermediate colours.

- White is the colour produced when the 7 colours of the spectrum remain
in the same proportion as in sunlight.

- Black is the sensation produced by absence of light.

YOUNG - HELMHOLTZ THEORY (TRICHROMATIC THEORY) OF COLOUR VISION:

- There are 3 types of cones containing 3 types of pigments
corresponding to 3 primary colours (red, blue & green).

- The 3 cone pigments:

<u>Pigment</u>	<u>Maximally absorbed wavelength</u>
1) Blue sensitive (short wave)	445 nm i.e. blue violet.
2) Green sensitive (middle wave)	535 nm i.e. green.
3) Red sensitive (long wave)	565 nm i.e. yellow.

Highly sensitive to red at a very
low threshold.

- Any coloured light stimulate the 3 types of cone unequally

The sensation of the colour perceived by the visual cortex depends on the
relative frequency of impulses from each type of the cones.

Equal stimulation of all types of cones gives the sensation of white
colour.

- Colour perception is a retinal phenomenon.

Colour translation is a cortical phenomenon depends on colour
coding.

NEURONAL MECHANISM OF COLOUR VISION:

- Cones information reaches the small parvo ganglion cells concerned with colours.
- Information carried by small ganglion cells → parvocellular neurons (small neurons) in the lateral geniculate body → neurons of blobs in the functional columns of visual cortex (colour sensitive neurons but lack orientation specificity) → to the lingual & fusiform gyri of the occipital lobe (area concerned with colour).

COLOUR BLINDNESS (ACHROMATOPSIA)

Definition:

Inability to perceive portion of the spectrum or inability to distinguish between colours recognized by a normal person.

Cause:

- 1) Hereditary disease 8% in males & 0.4% in females
Sex linked recessive trait (X – linked trait).
- 2) After retrobulbar neuritis i.e. inflammation of optic nerve.

Types:

1) Colour anomaly (Anomalous trichromate):

Patients have 3 cones system but one of them is weak.

- a- Protanomaly : weakness of red colour.
- b- Deuteranomaly : weakness of green colour (most common).
- c- Tritanomaly : weakness of blue colour.

2) Colour anopia (colour blindness):

a- Dichromate:

Patients have 2 cones system only & match their colour spectrum by mixing these 2 primary colours.

- a- Protanopia: red blindness.
- b- Deuteranopia : green blindness (2nd most common).
- c- Tritanopia: blue blindness.

b- Monochromate:

Patients have only one cone system & match their colour spectrum by varying the intensity of one primary colour.

AFTER IMAGE PHENOMENA

- Definition:

Visual sensation perceived after removal of visual stimuli.

- Types:

1) Negative after image:

If one looks steadily at a scene with bright, dark & coloured portions then he turns to look at a bright white surface.

- Bright portions appear dark due to light adaptation of retina.
- Dark portions appear bright due to dark adaptation of retina.

- Coloured portions appear as their complementary colours.

2) Positive after image:

If one looks to a bright object for a short time then he closes his eyes or looks to a dark surface, the image of the object is still seen with its original colour for few seconds.

FLICKER

- Definition:

It is intermittent light sensation produced by successive visual stimuli.

- Critical fusion frequency (CFF):

At certain stimulus frequency, flickers disappear & continuous light sensation results.

- Cause:

After discharge in the retina, so that the second stimulus continues the effect of the first one.

- Ferry Porter law:

CFF & log light intensity.

i.e. the sensation of flicker may reappear if the light intensity is increased. CCF is 20 HZ for rods & 50 HZ for cones because the duration of cone potential is shorter than that of the rod.

- Importance:

Flicker fusion is the basis of motion pictures.

Electroretinogram (ERG)

Definition:

It is a record of electrical changes occurring in the retina on exposure to light.

Method:

One electrode is placed on the cornea & the other (indifferent) on the forehead & connecting them through amplifier to polygraph.

Recording:

At rest there is a 6 mV potential difference between the front & back of the eye with the front positive.

When light strikes the eye the ERG shows 3 main waves:

a wave:

a small negative wave reflects the responses of rods & cones to light.

b wave:

a big positive wave reflects ganglion cells activities.

c wave:

a slowly rising positive wave that continues sometime after cessation of light.

It reflects activity of pigment epithelium.

A small negative wave is recorded when light is turned off.

Importance:

Diagnosis of retinal diseases in cases of difficult visualization of the retina is difficult as in dense cataract or cloudy ocular fluids e.g. in retinitis pigmentosa in which rods are first affected; the eye in a dark adapted condition shows ERG with absent a wave.

VISUAL PATHWAY

Photoreceptor (rods & cones) fibers pass to:

- 1) The 1st order neuron: bipolar cells.
- 2) The 2nd order neuron: ganglion cells.

Axons of the ganglion cells from:

- a-Optic nerve: 1.2 million fibres, 1/3 of them is derived from the macula..
- b-Optic chiasma: nasal fibres cross to opposite site, while temporal fibres don't cross.
- c-Optic tract.

The optic tract fibres of each side terminate in either of the following:

- i- Suprachiasmatic nucleus of the hypothalamus for controlling light evoked endocrine functions (circadian rhythm)
- ii- Pretectal nucleus for pupillary light reflex.
- iii- Superior colliculus for reflex eye directional movement.
- iv- Lateral geniculate body (thalamus).

Geniculo - calcarine fibres pass in optic radiation through the internal capsule to:

Visual cortex of the occipital lobe:

- a) Primary visual cortex = area 17 = striate cortex
- b) Visual association areas = areas 18 & 19 = peristriate area

LATERAL GENICULATE BODY: LGB

- It is a laminated structure consisting of 6 layers.
- Layers 2,3,5 receive input from the ipsilateral eye.
Layers 1,4,6 receive input from the contralateral eye.
- Layer 1 & 2 have large cells called magnocellular cells which receive input from the large ganglionic cells.

Function concerned with detection & stereoscopic perception & flicker.

- Layer 3 & 6 have small cells called parvo cellular cells which receive input from the small ganglionic cells.

Function concerned with colour, fine details & shape.

- Cells concerned with colour discharge to the clusters of cells called blobs in the visual cortex.

-Neurons of lateral geniculate body have the same organization of the receptive field of ganglionic cells.

VISUAL CORTEX

1- PRIMARY VISUAL AREA = AREA 17 = STRIATE CORTEX

Site:

In the calcarine fissure on the medial surface of the occipital cortex

Organization of neurons of primary visual area:

a) Visuotopic organization

- Peripheral parts of the retina are represented anteriorly.
- Macula is represented in the posterior parts & occipital pole.
- Upper halves of the retina are represented superiorly.
- Lower halves of the retina are represented inferiorly.

b) Primary visual cortex has six layers parallel to surface:

- Geniculo – calcarine fibers terminate in layer 4.
- Neurons of the visual cortex are known as feature detectors as they respond & analyze features of the stimulus.

c) Visual cortex is organized into columns perpendicular to surface.

- Each column (20 – 100 microns wide) contains 3 types of cells which have the same axis of orientation in a given column (orientation column).
- In between columns in layers 2 & 3, there are special clusters of cells called blobs or pegregion.

Function concerned with colour processing.

They receive projection from the parvo cellular layers of the geniculate body.

There are 3 types of cells in the visual cortex:

1) Simple cells:

- They have rectangular receptive fields with a specific axis of orientation.
- They respond to light or lines or edges with a certain particular orientation (vertical or horizontal).
- If a bar of light is rotated as little as 10 degrees from particular orientation, the firing rate of the simple cell is decreased & if the stimulus is rotated more, the response disappears.

2) Complex cells:

- They respond best to moving dark / light bars and edges without change in their orientation.
- They receive impulses from simple cells.

Functions of primary visual area:

It decodes information about contrast, colour, depth, form & movements.

2- SECONDARY VISUAL AREA = AREA 18 19 = PERISTRIATE AREA

Site:

It lies anterior, superior & inferior to the primary visual cortex.

Function:

Analysis of signals received from area 17 for:

- a) Detection of the nature of objects e.g. ball or pencil.
- b) Visual orientation & depth perception i.e. localization in space.
- c) Sends information to other cortical areas:
 - i- posterior parietal area : area 7.
 - ii- inferior temporal area : area 20 , 21.
 - iii- frontal eye field area : area 8.

LESIONS OF THE VISUAL PATHWAY

Lesion	Effect
1- Rt optic nerve	Blindness of Rt eye. Light reflex is absent.
2- Centre of optic chiasma i.e. nasal fibres	Bitemporal hemianopia (telescopic vision).
3- Optic tract	Contralateral homonymous hemianopia & light reflex is absent
4- Lateral geniculate body	Contralateral homonymous hemianopia & light reflex is present.
5- Optic radiation	
-extensive	Contralateral homonymous hemianopia & light reflex is present
-not extensive	Contralateral homonymous quadrantanopia.
6- Occipital cortex	Contralateral homonymous hemianopia & macular vision is spared (see below).
7- Macular region in area 17.	Contralateral hemianopic scotoma (loss of central eye field of both eyes).
8- Visual association area	Visual agnosia i.e. patient sees but can't understand.

Macular sparing is due to:

- 1- Macula is widely represented in the visual cortex.
- 2- Macular region receives extensive double blood supply from both middle & posterior cerebral arteries.

VISUAL FIELDS

Definition:

The maximal area of the external world seen by one fixed eye

Representation:

It is represented in area 17 in a diagrammatically opposite manner to that of retina i.e. the temporal half of retina sees the nasal half of the visual field & vice versa.

Normal field:

It is not circular, it extends 50 degrees upwards, 80 degrees downwards, 60 degrees nasally & more than 90 degrees temporally.

The field is most extensive for white target & becomes smaller successively when blue, red & green targets are used.

Importance of visual fields determination:

- 1- It helps to localize the site of lesion in visual pathway.
- 2- It localizes the site of scotoma (blind spot).
- 3- It helps in diagnosis of some retinal diseases e.g. retinitis pigmentosa causes loss of peripheral field before the central areas.

VISUAL ACUITY

Definition:

It is ability to see two points as two separate points.

It is usually determined by finding the minimal separation i.e. the degree of perception of details.

Visual angle is the angle subtended by light rays from 2 adjacent objects at the nodal point of the eye.

Requirements:

- 1) The 2 images must fall on 2 cones separated by at least one unstimulated cone i.e. retinal distance more than 2 microns.
- 2) The 2 points from an angle at the nodal point of the eye not less than 1 minute.

Note: If 2 points are focussed on one or two adjacent cones, the visual cortex recognizes them as one point.

Tests:

- 1) Broken black circles C on white background of Landolt.
- 2) Snellen's alphabetical letters.

The charts have certain marks that can be read by normal persons at 6, 9, 12, 18, 24, 36 & 60 meters (7 rows).

The person under test stands 6 meter from the chart to avoid accommodation & each eye is tested separately.

- If he is able to see all marks, he is 6/6.
- If he is able to see all marks up to 18 only, he is 6/18 his visual acuity is mathematical fraction which shows the ratio between one's acuity to that of the normal person.

Factors affecting visual acuity:

- 1) Degree of illumination & contrast between letters & background.

- 2) Refractive power of the eye i.e. acuity is decreased by errors of refraction.
- 3) Pupilloconstriction increases visual acuity by minimizing spherical & chromatic aberrations.
- 4) Visual acuity is maximal at fovea centralis.
- 5) Eye diseases like cataract, glaucoma & retinal detachment decrease visual acuity.

BINOCULAR VISION

Definition:

It is the ability to use both eyes without diplopia (double) vision.

Requirements:

- 1) The central parts of the 2 visual fields overlap to a great extent.

Notes:

- a) Binocular vision is most apparent in man & monkeys not in animals with eyes placed laterally in the head.
- b) The monocular field of vision in man is a crescent (35 degrees) at the outer part of each temporal field.
- 2) The 2 images fall on 2 corresponding points on the 2 retinac to give single visual sensation.
 - Fovea is at corresponding points in both retinac.
 - Diplopia occurs if there is unequal action of extraocular muscles (acquired squint) as the images do not fall on the corresponding points.
- 3) The 2 images must be identical in size, shape & colour.

Factors affecting binocular vision:

- 1) Considerable overlap of both visual fields.
- 2) The two eyes must have nearly equal dioptric power.
- 3) Normal extraocular muscles, so that both images of an object fall at the corresponding points of both retinac.
- 4) Normal visual cortex as fusion of images occurs in cortex.

Advantages:

- 1) Larger visual field.
- 2) The normal eye masks retinal defects on one eye (physiological or pathological).
- 3) Abnormal refraction of one eye masked by the normal eye.
- 4) Better stereoscopic vision.
- 5) Better depth perception.

N.B. Stereoscopic vision & depth perception are essentially monocular.

In monocular vision, depth & distance depends on:

- 1- Change in size: far objects are smaller.
- 2- Colours & details: fade with distance.
- 3- Occlusion: a front object covers an object behind it.
- 4- Distribution of light & shades.
- 5- The shadows which an object casts upon its surrounding.
- 6- Perspective: parallel lines appear to converge with distance.
- 7- Parallax: near objects move in opposite direction while far objects move in the same direction of head movement.

Stereoscopic vision

It is 3 dimensions vision.

It is better in binocular vision.

It allows the fusion of 2 slightly different images.

Thus, stereoscopic vision depends on:

- a) Factors that determine depth perception.
- b) Formation of slightly dissimilar images on both retinae.

EYE MOVEMENTS

- Each pair of the 3 sets of muscles to the eye is reciprocally innervated. So, if one looks to the right side, the right lateral rectus contracts & the right medial rectus relaxes, the left medial rectus contracts & the left lateral rectus relaxes
- The eyes are said to be in a position of rest when their direction is maintained by the tone of the ocular muscles & the gaze is straight & not directed to any particular point. The visual axis of both eyes is parallel.

TYPES OF EYE MOVEMENTS

1) Fixation movements

Aim to fix an object in field of vision.

a- Voluntary Fixation

Controlled by frontal eye field area (area 8).

Responsible for unlocking of eyes from one point to another point:

b- Involuntary fixation

Person automatically locks on the object of regard once it is found.

Controlled by the secondary visual area (area 19).

Unlocking is carried out voluntarily by the frontal eye field area.

2) Saccadic movements

Successive fixation eye movements e.g. during reading.

3) Smooth pursuit movements:

Fixation of eyes on moving objects.

e.g. optokinetic nystagmus : alternating slow & rapid eye movement which occurs when one looks through the window of a moving train & fixes an object.

4) Vestibular nystagmus

It maintains visual fixation as the head rotates.

Receptors: semicircular canals.

5) Convergence movements

It occurs on looking to near object.

Physiologic nystagmus

Slow continuous fine oscillatory movements, which prevent adaptation of receptors to constant illumination when the eyes keep fixing on a stationary object.

Strabismus or squint

- Incoordination of the external ocular muscles → loss of eye conjugate movements → visual images will not fall on corresponding retinal points → diplopia (double vision).

- Under the age of 6 years, permanent loss of visual acuity of the squinting eye (amblyopia exanopsia).

- Treatment:

a) Eye muscle training exercises using glasses with special prisms.

b) Surgical correction.

OPHTHALMOSCOPIC EXAMINATION OF THE EYE

- Ophthalmoscope is an instrument for retinal examination.

- Ophthalmoscope examination is used for:

1) Examination of retinal blood vessels (arteries, veins & arterioles) which help in diagnosis of systemic diseases affecting the vessels e.g. hypertension, diabetes mellitus & renal diseases.

Retina is the only place in the body where arterioles can be seen.

2) Examination of fovea & optic disc e.g. optic cupping occurs in glaucoma.

3) Diagnosis of retinal diseases e.g. retinal detachment.

4) Determination of error of refraction.

HEARING

SOUND WAVES

Sound consists of waves of **compression & rarefaction** of molecules.

Vibration of waves occurs in the same direction of wave travel i.e. longitudinal waves.

Unlike electromagnetic waves: e.g. light waves

1) Sound waves can not pass in vacuum.

2) Velocity is slower in gases (330 m/sec) than liquids (1500 m/sec) than solids (5000 m/sec in concrete and iron).

Velocity ++ with ++ temperature, but it is not affected by atmospheric pressure.

Velocity = wave length X frequency (Hz).

On hard surfaces, sound is reflected causing echo.

Sound waves do not cause any net flow of air in the direction of motion.

The air particle moves too & fro around its mean position.

Characters of sounds:

1) Frequency (pitch) of sounds:

- Low pitch sound = harsh sound.

High pitch sound = soft sound.

- Human ear can pick 20 - 20000 Hz i.e. 20 Hz to 20 KHz.

This corresponds to a wavelength range of 0.01 to 15 meter.

Human ear is most sensitive to 2000 to 5000 Hz i.e. it needs lowest amplitude (lowest threshold) to hear.

N.B. Wavelength is the distance between 2 successive peaks or bottoms i.e. cycle length.

- Human voice: 2000 to 5000 Hz i.e. 2 to 5 KHz.

- Ultrasonic waves (more than 20000 Hz) are used for:

1) diagnosis by echosonography.

2) treatment by using the heat produced by them.

2) Amplitude (intensity) of sounds:

- It is measured in term of energy per unit surface area per second.

- For practical purposes, it is measured in a relative way, using the threshold sound pressure level (pressure of just audible sound) for human hearing as a reference sound (P spl).

It is measured in decibels (dB) on a log arithmic scale (to reduce the very wide scale):

$$\text{dB} = 20 \text{ Log } \frac{\text{Sound pressure}}{\text{P spl}} \quad \text{or } 10 \text{ log } \frac{\text{Sound intensity}}{\text{P spl}}$$

Examples:

- 1- The amplitude of a sound pressure which has the same threshold sound energy equals $= 20 \text{ Log } 1/1 = 0 \text{ dB}$ i.e. **Just audible sound = 0 dB.**
- 2- Talking or whisper = 40 dB.
- 3- Normal conversation = 60 dB.
- 4- Traffic noise = 80 dB.
- 5- Pneumatic drill or airplane = 100 dB.
- 6- Jet plane = 120 dB.
- 7- Painful stimulus damaging the receptors = more than 140 dB.

- Minimum audibility curve

It measures the threshold intensity for hearing different sound frequencies in the human hearing range.

- Presbycusis:

Decreased ability to hear high sound frequencies in old age.

3) Quality of sounds (waveform)

Sounds may have the same frequency and amplitude but they differ in their waveform i.e. overtones.

Overtone overrides the fundamental line, giving specific waveform, which characterizes the sound.

THE STRUCTURE OF THE EAR

1) EXTERNAL EAR

It is formed of:

- a- Pinna.
- b- External auditory meatus.
- c- Tympanic membrane (drum).

Tympanic membrane (drum):

- 1 cm diameter.
- 0.1 mm thickness.
- It is cone shaped
- Its area = 55 mm^2
- Skin from outside and mucous membrane from inside cover it.
- The skin secretes bactericidal wax in the external ear.

Characters of tympanic membrane:

- i- It is **elastic**
- ii- It is **tense**
- iii- It is **aperiodic** i.e. it has no natural frequency.
Thus its rate of vibration = frequency of sounds i.e. **resonator**.
- iv- It has **damping** properties i.e. it stops vibrations when the sound stops.

FUNCTIONS OF EXTERNAL EAR:

1- Collection of sound stimuli.

2- Increase the sound pressure at the tympanic membrane:

The external ear (like trumpet) increases the total sound energy available to the tympanic membrane.

3- Sound localization:

However, sound localization is mainly by higher cortical interactions.

4- Protective function:

a) Wax:

- i- prevents entrance of harmful insects & objects.
- ii- has bactericidal effect.

b) Air in the external auditory canal is kept moist & near body temperature for proper functions of the tympanic membrane.

5- Function of tympanic membrane:

It transmits vibrations from external ear to the middle ear.

II) MIDDLE EAR:

It is formed of:

- a- Mesotympanum: a small middle ear cavity.
- b- Eustachian tube: a downwards & anterior extension.
- c- Mastoid air cells: a posterior extension.

Mesotympanum:

Middle ear cavity is lined by ciliated mucous membrane.

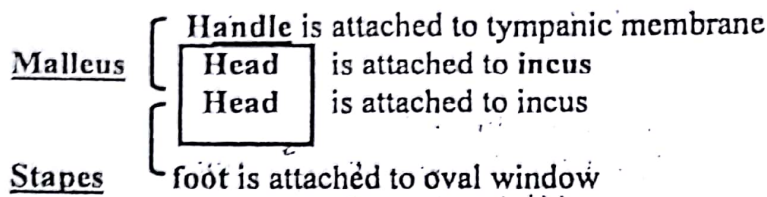
Contents:

1) Air coming through Eustachian tube.

2) Three ossicles:

Malleus, incus and stapes.

Fine mucous membrane folds suspend the ossicles



3) Two muscles of middle ear:

	Tensor tympani	Stapedius
- Insertion	- Handle of malleus.	- Neck of stapes.
- Nerve supply	- Trigeminal nerve.	- Facial nerve.
- Function	- It increases tension of tympanic membrane to allow optimum vibration.	- It prevents excessive inward movement of foot of stapes in oval window

Attenuation (acoustic or tympanic) reflex:

- Definition:

The muscles of the middle ear contract reflexly in response to intense (loud) sounds, thus reducing the ossicular conduction & sound transmission.

N.B. In loud noise, the tympanic reflex masks frequency below 1000.

- Reaction time of tympanic reflex:

40-160 msec, which decreases its protective effect against brief intense sound e.g. gunshot.

- Significance:

- 1- It prevents damage of auditory receptors by loud sound.
- 2- The muscles contract prior to one's own voice.

FUNCTIONS OF MIDDLE EAR:

1- It conducts (couples) sound energy to cochlea.

2- Physical protection of the cochlea.

3- The ossicular system transmits sound preferentially to only oval window of the cochlea.

This produces a differential pressure between the windows, which is required for the movement of cochlear fluid.

4- Functions of middle ear muscles & tympanic reflex (discuss).

5- Impedance (resistance) matching:

Middle ear matches the impedance of air to sound conduction in external ear to the much higher impedance of cochlear fluid in the inner ear.

If the fluid-containing cochlea is exposed to air carried sound energy, only 1% of this energy will be absorbed.

Middle ear amplifies the sound pressure to be effectively transferred from air to the fluid-filled cochlea.

Middle ear causes 22 times increase in pressure exerted on cochlear fluid.

Mechanism:

a- 17 times because the surface area of the drum is 17 times that of oval window.

b- 1.3 time because of the lever like action of ossicles.

6- Eustachian tube:

- It connects the middle ear with the nasopharynx.

- It equalizes the air pressure on both sides of tympanic membrane.

i.e. it renews air of middle ear & allows free movement of tympanic membrane.

- Normally the tube is closed but it opens:

- a- During swallowing, chewing & yawning.

- b- If the pressure in the middle ear exceeds that of atmosphere by 15 mmHg as in ascending to high altitude.

- During descent from high altitude, the external pressure pushes the drum inwards and may rupture unless the person swallows e.g. if the person is sleeping.

- If the tubes are opened permanently, the noises of breathing & talking will interfere with hearing.

- If the tubes are blocked as in common cold, the tympanic membrane is sucked in (due to gradual absorption of air) and the auditory acuity is greatly decreased.

Note:

It is lined by ciliated epithelium.

The cilia act in one direction allowing drainage of middle ear secretion that is helped by the oblique directions of the tube (in adults).

In children, the tube is short, wider & straight.

This allows easily entry of nasopharyngeal secretion & fluids causing middle ear infections.

III) INNER EAR:

It is formed of:

a- NON AUDITORY LABYRINTH

Utricle, saccule & semicircular canals.

b- AUDITORY LABYRINTH I.E. COCHLEA.

3 cm in length.

3 turns, actually 2.5 turns around modiolus (limbus).

3 canals (scalae).

Cochlea is divided by 2 membranes { vestibular i.e. Reissner's & basilar membranes; into 3 scalae.

The scala vestibuli & scala tympani:

- Communicate at helicotrema at the apex of the cochlea.
- Contain perilymph (derived from the CSF).
- Perilymph is similar to extracellular fluid (ECF) i.e. high Na^+ & low K^+ contents.

The scala media:

- Contains endolymph.
- Endolymph communicates with that of the non-auditory labyrinth.
- Endolymph is similar to intracellular fluid (ICF) i.e. low Na^+ & high K^+ contents.

At the base of the cochlea, 2 membrane-covered windows are present:

- Oval window which is occupied by the foot of the stapes.
 - Round window which is occupied by a thin secondary tympanic membrane.
- The vibrating middle ear bones cause the sound pressure wave to press on the oval window thus the round window bulges onwards.

The basilar membrane:

- Thin fibrous membrane, which is composed of 20-30 thousand bars.
- At the base of the cochlea, bars are **short** & respond to **high frequency sounds**.
At the apex of the cochlea, bars are **long** & respond to **low frequency sounds**.
- These fibres are stiff, elastic, rod like structures, which are fixed at their basal ends to the bony modiolus, while their distal ends are free {only attached by loose fibrous tissues}.
 - Basilar fibres decrease in diameter progressively from base to top of cochlea.

Organ of Corti:

- The receptor of hearing.
- It is situated on top of the basilar membrane from the apex to the base of the cochlea & consequently has a spiral shape.
- It contains short hairs {auditory receptor} cells, surrounded by tall supporting cells.
- The hair cells contain stereocilia, which pierce the tough membrane-like reticular lamina that is supported by the rods of Corti to the basilar membrane.
- The tectorial membrane is attached to the limbus (modiolus) at one end, rests on the hairs.
- Cochlear nerve fibers (afferent & efferent) enter via the tunnel of Corti to be in contact with the bases of the hair cells.
- Tight Junctions, between hair cells & adjacent supporting cells, prevent endolymph from reaching the bases of hair cells.

Thus the bases of the hair cells are bathed in perilymph.

While the processes of the hair cells are bathed in endolymph.

This is important for generation of action potential in cochlear nerve.

Two groups of hair cells:

	Inner hair cells	Outer hair cells
- <u>Site</u>	Medial to the tunnel	Lateral to the tunnel.
- <u>Number of rows</u>	One	Three
- <u>Number of cells</u>	3500	20000
- <u>Innervation</u>		
a- Afferent	90 – 95% of afferents	5 – 10% of afferents.
b- Efferent cholinergic	Few	Most of efferents.
- <u>Functions</u>	Auditory receptors	Improve hearing by affecting the vibration of the basilar membrane.

MECHANISM OF HEARING:

1) TRANSMISSION OF SOUND TO THE INNER EAR:

a) Ossicular route:

The main route.

It is very efficient.

Sound waves are transmitted to the oval window by the tympanic membrane and auditory ossicles.

Advantage of ossicular route: (Functions of middle ear).

b) Bony route:

Inefficient route.

Skull bone is made to vibrate by:

- i- tuning fork applied to the skull.
- ii- extremely loud sound.

c) Air route:

It is not efficient.

It becomes only important when the tympanic membrane and the auditory ossicles are damaged.

N.B. For practical purposes air conduction stands for normal ossicular route.

2) MECHANISM OF STIMULATION OF AUDITORY NERVE:

GENERATION OF RECEPTOR POTENTIAL:

- The endolymph contains a high concentration of K^+ (135 mEq / L) and is electrically positive (+80 mV) in comparison to the perilymph (endolymphatic or endocochlear potential).

Endolymphatic potential is generated by K^+ transport into scala media by the stria vascularis.

- Hair cells, like all other cells, contain a high concentration of K^+ & are electrically negative in comparison to the perilymph

A very large potential difference (more than -100 mV) exists between the hair cell & endolymph.

- Sound Waves entering the inner ear from the oval window spread along the scala vestibuli as a traveling wave.

Most of the sound energy is transferred directly from the scala vestibuli to the scala tympani.

Very little of the sound wave reaches the helicotrema at the apex of the cochlea.

- As the sound energy passes from the scala vestibuli to the scala tympani, it causes the fluid within the cochlea to vibrate & the basilar membrane to **vibrate up & down**.

- The up & down motion of the basilar membrane causes the organ of Corti to vibrate up & down, which, in turn, causes the stereocilia of hair cells to **bend back & forth** due to the attachment of the stereocilia to the tectorial membrane.

- When the organ of Corti moves up, the stereocilia bend away from the limbus $\rightarrow$ opening of K^+ channels $\rightarrow K^+$ flows into the cell & hair cell depolarizes $\rightarrow$ opening of Ca^{++} channels $\rightarrow Ca^{++}$ ions enter the hair cell $\rightarrow$ release of a synaptic transmitter $\rightarrow$ stimulation of auditory nerve fiber.

When the organ of Corti moves down, the reverse occurs.

3) AUDITORY PATHWAY: i.e. transmission of auditory impulses.

Each cochlea is bilaterally represented in both temporal lobes (mainly the opposite side).

Receptors:

Inner hair cells of organ of Corti.

1st order neuron:

Spiral ganglia: in modiolus of cochlea.

Axons: Cochlear division of 8th nerve.

2nd order neuron:

Dorsal & ventral cochlear nuclei in medulla.

Axons: transmit auditory impulses via a variety of pathways & may terminate in or bypass these nuclei.

a- Superior olivary nucleus especially of the opposite side.

b- Nucleus of trapezoid body.

c- Nucleus of lateral lemniscus.

d- Inferior colliculus.

3rd order neuron:

Medial geniculate body (MGB) on both sides in thalamus.

Axon: auditory radiation.

Center:

Auditory cortex

It lies in the superior temporal gyrus.

There are two separate areas:

a- The primary auditory cortex

It is directly excited by impulses from MGB.

b- The secondary auditory cortex (auditory association cortex).

It is excited secondarily by impulses:

1- from the primary auditory cortex.

2- from thalamic association area near MGB.

Functions of auditory cortex:

a- Perception of sound & gives the person the sensation of sound pitch.

b- Detection of the direction from which sound comes.

c- Recognition of patterned sequence of sounds as during speaking or listening to a music.

d- Corticofugal fibers from auditory cortex to the organ of Corti are inhibitory. This could allow a person to direct attention to sounds of particular qualities, while rejecting sounds of other qualities as in listening to a single instrument in a symphony orchestra.

Notes:

- Many collaterals in the auditory tract pass directly into the reticular activating system of the brain stem to help maintain wakefulness.

- A high degree of spatial orientation is maintained in the fiber tracts from the cochlea all the way to the cortex.

- Bilateral destruction of auditory cortex:

It reduces the sensitivity for hearing, but not cause complete deafness.

It abolishes recognition of tonal pattern & sound localization.

- Unilateral destruction of auditory cortex slightly reduces hearing in the opposite ear but does not cause deafness in the ear.

- Lesions in the auditory association area do not decrease the person's ability to hear & differentiate sound tones.

However, he will often be unable to interpret the meaning of the sound heard.

4) AUDITORY ENCODING: a type of sensory encoding

Definition:

It is the ability of the auditory system to **determine (discriminate):**

a- Sound frequency (pitch)

b- Sound intensity (loudness)

c- Sound localization in space

d- Tonal & sequential sound patterns.

A) Determination of sound frequency

It is explained in 2 ways:

1- The place principle:

The major determinant of the pitch is the PLACE in the organ of Corti that is maximally stimulated.

The travelling wave caused by sound vibrations produces peak depression of the basilar membrane & consequently maximal receptor stimulation AT ONE POINT.

The distance between this point & the stapes is inversely related to the pitch (frequency) of the sound:

i- Low frequency sound produces maximal stimulation at the apex of the cochlea.

ii- High frequency sound produces maximal stimulation at the base of the cochlea.

2- Tonotopic organization:

There is spatial organization (orderly arrangement) of the nerve fibers & neurons of different nuclei in the auditory pathway ALL THE WAY from the cochlea to the cerebral cortex.

e.g. Neurons responding best to low-frequency sounds will be located at one end of a nucleus, while neurons responding best to high-frequency sounds are located at the opposite end of the nucleus.

B) Determination of sound intensity:

The higher the intensity of sound, the more will be:

1- the frequency of firing in an auditory nerve fiber i.e. Weber-Feshner law

2- the portion of the basilar membrane vibrated i.e. the number of activated auditory nerve fibres.

N.B. Outer hair cells do not become stimulated significantly until the vibration of the basilar membrane reaches high intensity.

C) Determination of sound localization:

It depends on:

1- Intensity difference

The sound is louder in the closer ear.

2- Phase (time) difference

At low frequencies, there may be time differences in the sound waves striking the two ears.

N.B. The pinnae of the 2 ears help discrimination the source of sound.

D) Determination of sound patterns:

Auditory cortical neurons can recognize a combination or sequence of tones, one following the other, in a particular pattern i.e. they respond specifically to a shift from high to low frequency.

Lesions of auditory cortex may not impair the ability to discriminate frequency, but it causes inability to recognize a patterned sequence of sounds (as in music).

HEARING DISORDERS:

TINNITUS

It is a ringing sensation in the ears.

Cause:

Irritation of either inner ear or vestibulo-cochlear nerve.

DEAFNESS

2 Types:

Items	Conductive deafness	Nerve (sensori-neural) deafness
<u>Causes</u>	- Blocking of external ear e.g. wax. - Diseases of middle ear. - Stiffening of foot of stapes (Otosclerosis). - Perforated drum.	- Lesion of inner ear e.g. Streptomycin & garamycin. - Lesion of auditory pathway. - Lesion in CNS is not found clinically.
<u>Characters</u>	1. Bone conduction is better. 2. All frequencies are uniformly affected.	1. Bone and air conduction are equally affected. 2. One frequency may be more affected.

Tests for deafness:

1- Weber test:

The base of vibration tuning fork is placed on the center of patient forehead.

In normal person, sound is equally heard in both ears.

In conductive deafness, sound is better heard in the diseased ear (not masked by noise from the external world).

In nerve deafness sound is better heard in normal ear.

2- Rinne test:

A vibrating tuning fork is placed on the mastoid process until the subject no longer hears it, then the fork is held in air next to ear.

In normal person, vibrations in air heard after bone conduction is over.

In conductive deafness, he does not hear in air after bone conduction is over.

In nerve deafness both bone & air conduction are impaired.

3- Audiometry:

It determines hearing loss in decibels for the different frequencies.

It provides the subject with pure tones of various frequencies through earphones.

At each frequency, the threshold intensity is determined & plotted on a graph as a percentage of normal hearing.

It provides an objective measurement of degree of deafness.

THE CHEMICAL SENSES (SMELL AND TASTE)

OLFACTION (THE SENSE OF SMELL)

IMPORTANCE OF OLFACTION:

- 1- It determines the flavors of food.
 - 2- It is essential for gastrointestinal functions.
 - 3- Avoiding dangerous liquid & volatile substances.
 - 4- It has a role in sexual behavior.
 - 5- Smell & taste have a unique ability to trigger long term memories.
- N.B. The sense of smell is not well developed in man.

OLFACTORY MUCOSA AND OLFACTORY RECEPTORS:

Site:

Olfactory mucosa 5 cm².

On the superior nasal concha adjacent to the nasal septum.

It is not directly exposed to the flow of inspired air except by sniffing.

It distinguished from the surrounding respiratory mucosa by:

- 1- The presence of Bowman's glands which secrete mucous.
- 2- The absence of the rhythmic ciliary beating.
- 3- The presence of distinctive yellowish brown pigment.

Innervation

Olfactory & trigeminal nerves.

Histologic structure: 3 cell types

1- Olfactory (receptor) cells: bipolar cells

Dendrites form a knob with 6 - 12 cilia.

Axons form the olfactory nerve.

2- Supporting cells: columnar cells with microvilli.

3- Basal cells: stem cells from which new receptor cells are formed.

PROPERTIES OF OLFACTORY RECEPTORS:

1- Extreme sensitivity:

2- High ability for discrimination of odours:

Olfactory receptors can discriminate about 10,000 odours.

3- Low ability for discrimination of odours intensity:

At least 30% change in concentration must occur to detect the change.

4- Rapidly adapting

Caused by receptor adaptation or central effect.

5- Specificity

One receptor responds to many odours.

No two receptors have identical responses.

Sensory perception is based on the pattern of activated receptors.

6- Adsorption of odorant molecules to the plasma membrane of cilia of receptor cells generates a receptor potential.

7- The electrical response recorded from the olfactory mucosa in response to an olfactory stimulus is called electro-olfactory gram (EOG).

Amplitude of electrical response $\propto$ intensity of the stimulus.

AN ODOROUS MATERIAL SHOULD BE:

1- Volatile.

2- Slightly water soluble to dissolve in mucous covering receptor cells.

3- Slightly lipid soluble to dissolve in cell membrane of receptor cells.

STIMULATION OF OLFACTORY CELLS:

- RMP -55mV.

- Firing level - 30mV (very close to RMP).

- The odorant substance binds with a receptor protein (odorant binding protein) on cilia of receptor cells.

- Such binding activates G protein $\rightarrow$ activation of adenylyl cyclase or phospholipase $\rightarrow$ opening of Na channels $\rightarrow$ receptor potential.

OLFACTORY PATHWAY

Receptors:

Olfactory cells

1st order neuron:

Olfactory cells (bipolar cells)

Dendrites form knob with 6 - 12 cilia

Axons form olfactory nerve; which pierces the cribriform plate.

Olfactory nerve enters the olfactory bulb & forms excellent spatial summation with:

2nd order neuron:

Large mitral cells & small tufted cells in olfactory bulb.

N.B. Olfactory nerve fibres synapse with the dendrites of mitral & tufted cells in globular synapses called olfactory glomeruli.

Axons form olfactory tract, which divides into:

a) Medial pathway to medial olfactory area

A group of nuclei anterior to hypothalamus.

Function:

It controls the primitive responses to smell such as licking the lips and salivation.

b) Lateral pathway to:

1- Lateral olfactory area which includes:

i- Prepyriform & pyriform cortex.

ii- Cortical portion of amygdaloid nuclei.

Function:

Learning to like or dislike food depending upon past experience.

2- Orbito frontal cortex via the thalamus

Function:

It helps in conscious analysis of odours e.g. burning of food.

Notes:

- Olfactory bulb contains local inhibitory interneurons viz, granule cells & periglomerular cells which form dendro-dendritic circuits with mitral cells to inhibit them.
- Olfactory bulb receives inputs from the contralateral olfactory tract via the anterior commissar.

SMELL ABNORMALITIES

1) Anosmia:

Loss of smell e.g. in common cold.

Anosmia to certain odours may occur due to absence of their membrane binding proteins (Hereditary disease).

2) Dysosmia:

Distorted sense of smell (Hereditary disease).

3) Hyposmia:

Decreased smell sensitivity.

4) Hyperosmia:

Increased smell sensitivity.

It occurs in Addison's disease

TEST FOR SMELL

Use familiar nonirritant substance e.g. coffee to avoid the irritation of the trigeminal nerve that leads to apnea, sneezing & lacrimation.

TASTE

IMPORTANCE:

It helps in food selection.

TASTE BUDS AND TASTE RECEPTORS:

Site:

Taste receptors are located within taste buds, which in turn are located within papillae.

Distribution:

Tongue papillae, hard palate & soft palate, epiglottis and in the pharynx.

Structure:

Taste bud is a collection of:

- 1) Numerous supporting cells.
 - 2) 40 - 60 taste cells (modified epithelial cells) that communicate with gustatory nerve ending by synaptic transmission.
- Taste bud has one taste pore for substance to enter.
 - The taste receptors are located on microvilli which project from the taste cells into the taste pores.

Specialization:

- At low concentration, each taste bud responds to only one of the 4 primary taste stimuli (sweet, salty, sour and bitter).
- At high concentration, most of taste buds respond to more than one of the primary taste stimuli.

Regeneration:

- Each taste cell has a life cycle of only a few days.
- New taste cells arise from the supporting epithelial cells.
- The afferent neuron converts an epithelial cell into a taste cell, while nerve transection cause the disappearance of taste cells.

Papillae:

4 types (3 containing taste cells and one contains mechanical receptors)

A- Gustatory papillae:

1- Fungiform papillae:

Located on anterior 2/3 of tongue.

Each contains 8 - 10 taste buds.

2- Circumvallate papillae:

Located in a V shaped row of 7 - 12 on the posterior part of tongue.

Each contains 200 taste buds on the sides of papillae.

3- Foliate papillae:

Located on lateral border of tongue anterior to circumvallate papillae.

It contains many cells.

B- Mechanical (filiform) Papillae:

They play a role in breaking up food particles.

They are located at dorsum of tongue.

TASTE MODALITIES:

4 basic taste modalities

1- Sweet:

Tasted at the tip of the tongue.

e.g. organic molecules including sugars, glycerols & aldehydes.

2- Salty:

Tasted at anterior half of each side of the tongue.

e.g. ionizable salts (NaCl)

3- Sour:

Tasted at the posterior half of each side of tongue.

e.g. H^+ of acids.

4- Bitter:

Tasted at the back of the tongue.

e.g. alkaloids such as quinine and caffeine.

N.B. Taste must be distinguished from flavor, which includes the olfactory, tactile & thermal characters of food in addition to taste e.g. Hot food has different flavor from cold one.

MECHANISM OF STIMULATION OF TASTE RECEPTORS:

Taste producing substances must dissolve in saliva.

Taste receptors respond to taste stimuli in a variety of ways:

1) Sweet - tasting substances depolarize taste receptors by

i- opening Na^+ channels.

ii- closing K^+ channels by ++ cAMP via activation of adenylcyclase.

2) Salty - tasting substances depolarize taste receptors by

opening Na^+ channels

3) Sour- tasting substances depolarize taste receptors by

increasing intracellular H^+ concentration, which closes K^+ channels.

4) Bitter- tasting substances depolarize taste receptors by

++ inositol triphosphate (IP3) $\rightarrow$ ++ Ca^{++} level $\rightarrow$ release of synaptic transmitter.

TASTE PATHWAY:

Receptors:

Taste cells of taste buds

1st order neuron:

Site

Anterior 2/3 of tongue

Posterior 1/3 of tongue

Palate, epiglottis, pharynx

Fibres in these nerves unite in medulla to form tractus solitarius

Ganglia

General nerve

Facial

VII

Glossopharyngeal

IX

Vagus

X

Ganglia

Geniculate

Superior petrosal

Nodose

2nd order neuron

Nucleus tractus solitarius

Axons cross to opposite side and join the medial lemniscus ending with the fibres for touch, pain and temperature in thalamus.

3rd order neuron

Specific relay nuclei in the thalamus.

Center:

Taste does not have a separate cortical projection area.

It is represented in the lower part of the postcentral gyrus in the parietal lobe that receives cutaneous sensation from the face, then to somatic psychic (association) area (area 5,7).

GOOD LUCK